

Projection, Place, and Point-of-View in Research through Design

Steven Dow, Wendy Ju and Wendy Mackay

AQ1: Please confirm if the order in which your names appear here is ok, or if it should be how they appear in the table of contents.

The paradigm of Research through Design (RtD) combines the forward-thinking, artifact-generating practices of design with the knowledge-generating goals of research (Koskinen et al. 2011; Zimmerman et al. 2007; Zimmerman et al. 2010; Fallman 2003; Nelson & Stolterman 2003). This new epistemology has emerged as a complement to traditional lab experimentation and field observation research, particularly in design-oriented disciplines such as Human-Computer Interaction (HCI) where researchers often create artifacts to understand people in a new light (Fallman 2003). In RtD, artifacts are not the end goal, but a means for framing an alternative future and uncovering human needs, desires, emotions and aspirations (Carroll & Kellogg 1989; Dunne 2011; Gaver et al. 1999; Gaver et al. 2004).

As more researchers adopt this approach, there is an increasing need to explore the rationale for and methodological implications of RtD and to understand how to

judge the validity of its research contributions. This chapter has several goals: (1) to define Research through Design and differentiate it from traditional epistemologies in the human sciences; (2) to describe key aspects of this research orientation with respect to how it *projects* a future state, where it *places* design artifacts to gather data, and how researchers impose their philosophical *points-of-view*; (3) and finally, to discuss some of the standards the research community has adopted to evaluate research-through-design contributions. We hope this treatment of Research through Design helps to expand its definition and provides a useful framework for researchers and students in the design research community.

WHAT IS RESEARCH THROUGH DESIGN?

In 2004, Bill Gaver's design studio at the Royal College of Art created a rather peculiar



Figure 18.1 Gaver's Drift Table exemplifies research through design.

artifact, an electronic coffee table with a tiny display of aerial photography that moves slowly based on the weight distribution on its surface (Gaver et al. 2004) (see Figure 18. 1). Gaver and his colleagues were not interested in whether people wanted to buy the Drift Table. It was never intended to be widely adopted or commercially viable, but rather, to serve as an object of inquiry. This provocative artifact helped Gaver and his colleagues to investigate non-routine household activities and 'ludic' emotions, such as curiosity and reflection.

In Research through Design (RtD), researchers develop and deploy novel artifacts – digital or physical – as a tactic to learn about specific aspects of the human experience (Frayling 1993). While traditional design practice focuses primarily on producing artifacts, systems, or services to make some cultural or economic impact (Kolko 2007; Kelley 2002; Buxton 2007), RtD uses designed artifacts to produce theory (Carroll & Kellogg 1989; Fallman 2003;

Zimmerman et al. 2007; Zimmerman et al. 2010). This design-oriented research method goes beyond the artifact to make insights about people, culture, or interactions. Moreover, RtD is distinct from 'research on design', the study of what people do when they do design, and 'research for design' which focuses more on how to improve design practice (Forlizzi et al. 2009; Dow 2011).

RtD leverages design as a fundamental research method, and hence shares many characteristics with professional design practice. Design researchers employ techniques such as sketching and prototyping (McCloud 1993; Davidoff et al. 2007; Schrage 1996). They gather feedback through user studies and design crits (Tohidi et al. 2006; Dow et al. 2011). Much like practitioners, design researchers discover critical dimensions of a design space through a process of iteration and experimentation (Dow et al. 2009; Dow et al. 2010; Kelley 2002). RtD also strives to project a future state of the world and to

engage real-world human response (Simon 1996; Gaver et al. 2003). The key distinctions between RtD and design practice is that the primary activity of design researchers is to theorize and formalize knowledge about how and why people interact with design artifacts (Koskinen et al. 2011; Zimmerman et al. 2007; Zimmerman et al. 2010; Fallman 2003; Nelson & Stolterman 2003).

From a research perspective, design allows researchers to investigate how people think, behave or interact in scenarios that have yet to be, or may never be. It is this orientation towards the future – towards ‘what might be’ (Peirce 1998; Martin 2009) – that makes research through design powerfully different from traditional research paradigms. By thinking forward, RtD acknowledges the reality of change in the world and the role of human agency in that change (Nelson & Stolterman 2003). Design researchers prototype their visions of the future, seek to understand the implications of those visions, and work to communicate and disseminate their insights to a broader audience.

Research through design is a knowledge-building endeavor that falls outside the boundaries of traditional human research (Gaver 2012; Nelson & Stolterman 2003), such as ethnography and psychology experiments. In anthropological ethnography, researchers describe people and activities in a specific time and place (Dourish 2006; Malinowski 1984). Designed artifacts often reside in such environments, but the ethnographer does not place them there. Ethnographers often take care not to contaminate the local culture through their very presence or by introducing new artifacts (LeCompte 1999). Some ethnographers advocate reflexivity, to describe how the researcher gained access to their site and how personal circumstances might affect their data (Geertz 1977; Rode 2011). While RtD frequently employs ethnographic-style methods for data gathering, its practitioners take a more liberal orientation

towards intervention. Design researchers often take the liberty of explicitly intervening by designing and introducing artifacts, and observing the subsequent effects in some context (Gaver et al. 2004). For example, to better understand how to improve work practices in air traffic control towers, Mackay et al. performed detailed ethnographic observations of how controllers use paper flight strips (Mackay, 1999), but then conducted research through design by developing a system to track and graphically augment the physical appearance of the strips with digital information (Mackay et al. 1998).

Research through traditional laboratory experimentation provides another point of contrast. Lab experimentation values repeatability, generalizability, and internal validity (Creswell & Clark 2006). Lab researchers carefully isolate key factors and create measures to understand the causal relationships of specific stimuli (Stangor 2010). RtD also borrows from laboratory-based methods to study how people react to new artifacts (Frens 2006). The formal lab setting helps to control the multitude of factors under observation. While controlled experiments manipulate one variable at a time, design-based lab studies may explore a wide variety of variables (Frens 2006; Ju & Takayama 2009; Dow et al. 2007). For example, Dow and colleagues contrasted augmented reality with desktop-based interaction using the same interactive narrative (Dow et al. 2007) (see Figure 18.2). This broad-sweeping experiment helped the researchers study how a range of variables affected player engagement. In the lab, design researchers use artifacts to explore multiple dimensions of a design space.

Research through design represents a new epistemology. It not only introduces new artifacts, it employs a very different kind of logic. With field observation, researchers use *inductive* reasoning to draw logical conclusions from data (Copi & Cohen 2005). With lab experiments, researchers utilize



Figure 18.2 Dow and colleagues conducted semi-controlled lab studies with different interfaces to the interactive drama *Façade*.

deductive reasoning to predict outcomes based on theory (Creswell & Clark 2006). Design researchers, on the other hand, use *abductive* reasoning to conjecture a probable future based on an incomplete set of observations (Kolko 2011; Peirce 1998). They ask ‘what-if questions’ based on a set of ideals and agendas (Fallman, 2003). By focusing on the possibilities that arise from some future design (Moggridge 2007), design researchers are bound to different epistemological commitments than pure ethnographic field studies, traditional psychology experiments, or other research approaches, such as simulation or historical perspectives (Axelrod 1997; Wyche et al. 2006).

Runkel and McGrath argue that no scientific research method stands alone, since each approach involves tradeoffs, and thus they urge researchers to triangulate methods (Runkel & McGrath 1972). Mackay extends this reasoning to HCI, demonstrating how researchers can include design methods as part of this process of triangulation (Mackay & Fayard 1997). RtD brings to the table several features that other methods lack: an

orientation towards abductive logic, an exploration of yet-to-be-defined variables, and the invention of artifacts that serve as blueprints and provide implications for future designs.

HOW RESEARCH THROUGH DESIGN TAKES SHAPE

Research in the natural and human sciences may start from a theoretical, empirical or design perspective, but, in order to qualify as research, it must contribute to theory. Research *through* design contributes theory by reflecting on tangible projections of the future. These research artifacts serve diverse agendas and take on many shapes and forms (Carroll & Kellogg 1989; Gaver 2012). In the field of HCI, research through design addresses topics as diverse as sustainability, family communication health, spirituality, entertainment, and productivity. HCI researchers often produce various artifacts, ranging from paper-based rapid prototypes to full-scale physical prototypes that leverage emerging

technologies. This chapter acknowledges this diversity and outlines a framework to discuss the myriad of ways research through design takes shape.

We introduce a framework to map research through design along three key dimensions:

- **Projection:** how far the design looks into the future;
- **Place:** where and how design artifacts gather knowledge;
- **Point-of-View:** the rhetorical stance of the design researcher.

Design researchers must choose how far forward in the future to investigate, how and where to observe their designs in action, and what philosophical stance to take in conducting and communicating their design research. The next sections explore each of these in turn, with examples from the HCI community to demonstrate the choices available to design researchers.

Projection

Design is always about the future, exploring what could be, beyond what already is (Nelson & Stolterman 2003). Design researchers seeking to generate theory can choose how far into the future to project their designs, setting their sights on the long-, mid- or near-term. The timelines of these different design trajectories deeply affect the character and quality of research through design. We characterize three stages of projection:

Design breakthroughs introduce a novel idea that fundamentally changes a field, opening possibilities that inspire new designs and new theory;

Point designs populate the design space with examples that define, explore and extend the theoretical dimensions of the design space;

Design identify key theoretical elements

principles that can be taught and employed by design practitioners.

Although these stages discretize a continuum, the categories help to indicate how design researchers generate different kinds of knowledge based on their degree of projection. Rare innovative ideas spark a sense of wonderment and often push the limits of current technology, but are often too expensive or impractical for current products. For design practitioners, these design breakthroughs serve as inspiration. As the design space becomes populated with point designs, the underlying technologies often become cheaper and more accessible, which often leads to early commercial products. Eventually, within a problem space, principles emerge that clearly articulate why certain design choices are preferred (Alexander et al. 1977). Design professionals and educators use these principles to inform their work (Duyne et al. 2006).

Design Breakthroughs

The most future-oriented, and thus most rare, design projections involve radical reconceptualizations of a design problem. Rather than exploring an existing design space, these design projections inspire new design spaces. Long-term design projections are often preceded by an ‘a-ha’ moment (Parnes 1975), an insight that enables the designer to conceive of an entirely new set of design possibilities. Design breakthroughs often take the form of a video such as Apple’s 1987 Knowledge Navigator Video, or a diorama such as Norman Bel Geddes’s Futurama exhibit at the 1968 World’s Fair, or a technical demo that can serve as a ‘proof of concept’. Design breakthroughs are often based on technology that does not yet exist, at least not in an easily incorporated form, and may use techniques such as storyboards, exhibits, or ‘Wizard of Oz’ enactments to simulate the experience (McCloud 1993; Truong et al. 2006; Dow et al. 2005).

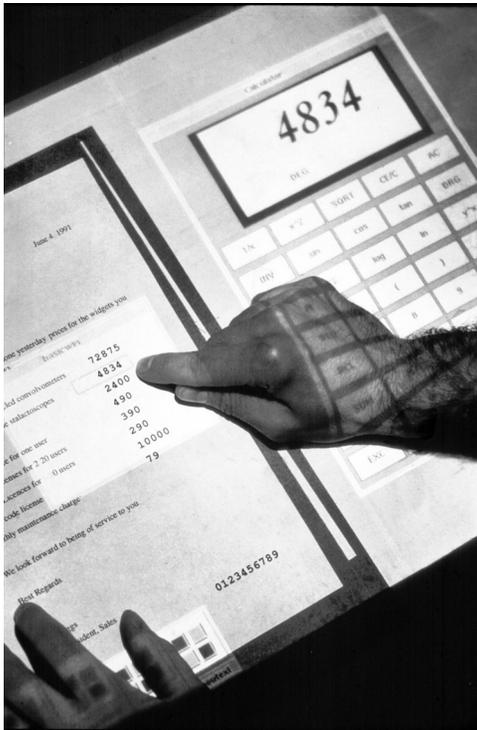


Figure 18.3 Wellner's DigitalDesk demonstrated the idea of mixing virtual documents into a physical space.

Successful breakthroughs produce knowledge by offering designers, users and other researchers a glimmer of what is possible. Often, a demonstration of key technologies or interfaces help distinguish these research contributions from science fiction. A classic example is Wellner's DigitalDesk (Wellner 1993), which seamlessly combined physical and virtual documents in a shared physical environment (see Figure 18.3). Similarly, Bishop's Marble Answering Machine offered a novel way to use physical marbles to interact with digital audio messages (Bishop 1992). Bishop communicated the concept by creating an animated sketch. When other researchers focused on digitizing everything paper, the DigitalDesk and the Marble Answering Machine helped usher in a revolution in tangible computing

and encouraged designers to explore novel ways of integrating physical and virtual objects (Ishii & Ullmer 1997; Klemmer et al. 2001). They challenged the then-prevailing belief that the coming of the digital age marked an end of the material world.

Point Designs

Upon realizing the potential of a new design space, other researchers populate it with novel 'point designs' (Card 1996; Gaver 2012). Point designs help define and clarify the dimensions that comprise a design space. Rather than exploring each dimension individually, each point design embodies the intersection of multiple design dimensions, extends existing dimensions, and identifies previously undetected holes within the design space. Over time, as many researchers contribute point designs, it extends to accommodate new user groups, new contexts and new technologies. Point designs are typically more developed than design breakthroughs and take the form of working prototypes that can be tested by users in limited settings. For example, PapierCraft extended Wellner's DigitalDesk work by enabling authors to annotate paper copies of a document and implement the changes online (Liao et al. 2008). Going beyond DigitalDesk, PapierCraft featured fully functional prototypes and addressed more pragmatic issues facing office workers.

Similarly, Ishii's musicBottles (see Figure 18.4), which play musical pieces when bottle stoppers are removed, act as a poetic counterpoint to Bishop's Marble Answering Machine and provide another example of using a tangible interface to control digital audio content (Ishii et al. 2001). Each new design extends and fleshes out a concept and pushes the boundaries of a design space. The resulting portfolio of point designs, created by the community of designers, serves as the foundation for the creation of design principles.



Figure 18.4 Ishii's musicBottles extended Bishop's concept of using tangible objects to control digital audio (© Hiroshi Ishii).

Design Principles

As point designs populate a design space, researchers explicate the underlying principles that govern the domain and capture this knowledge as design patterns, guidelines and theories. *Design patterns* are collections of designs that work best in different scenarios for different purposes (Alexander et al. 1977; Duyne et al. 2006). For instance, Landay and Borriello championed the creation of design patterns in ubiquitous computing. They argue, 'by communicating solutions to common problems, design patterns make it easier to focus efforts on unique issues' (Landay & Borriello 2003). Design patterns help researchers and practitioners avoid reinventing solutions to known problems and provide 'framing constructs' for further designs (Zimmerman et al. 2010).

Design guidelines are organizing constructs that facilitate designing or experimenting in a space. For example, Nielsen's 10 heuristics for UI design (Nielsen 1990) and Spool's usability engineering guide (Spool et al. 1998) capture best practices for HCI. Critics argue that guidelines oversimplify design problems

and provide more value towards the review of existing designs, rather than the creation of new designs. Guidelines rarely explain how to manage conflicts between rules, nor do they encourage truly innovative designs (Greenberg & Buxton 2008).

Design theories are more elaborate and general-purpose: they attempt to speak to deeper 'truths' in a design space. For example, Beaudoin-Lafon and Mackay theorize generative principles for interaction techniques (e.g. reification, polymorphism and reuse) and demonstrate how they can be used individually and collectively to address a wide set of commands with a simpler interface (Beaudouin-lafon & Mackay 2002). Similarly, Suchman's theory about situated action and Hutchin's concept of distributed cognition have deeply influenced several decades of interaction design (Hollan et al. 2000; Suchman 1987).

Place

Design researchers gain insights by placing designs into situations with people. Just as

Comment
{SD1}:
we can look it up
if we need to,
but it seems
unnecessary

Comment
{RC2}:
Give page
number for
quote?

researchers come from different scholarly and philosophical traditions, they deploy their design experiments differently. ‘Place’ refers not just to the deployment location, but to data gathering methods and trade-offs associated with each setting.

<i>Laboratory settings</i>	create controlled settings and carefully monitor interactions around new designs;
<i>Field deployments</i>	place artifacts into real-life settings where people actually work and play;
<i>Exhibitions</i>	present designs to a broader public, inviting interaction and discourse around the work’s conceptual underpinnings.

Each setting incurs important advantages and limitations. For better triangulation, many design researchers place their designs in several settings to better understand the theoretical implications. A small-scale field deployment may yield different, yet complementary, insights than a large-scale lab study. This section describes the trade-offs of different placement models with examples of each.

Laboratory

In a laboratory setting, potential users are invited to interact with a new artifact or service. The design researcher can explore variations within a specified design space while controlling or excluding irrelevant factors. New designs are often compared to alternative or existing designs using a variety of quantitative and qualitative measures, including performance metrics and subjective opinion.

Jonsson et al.’s experiments with in-car voice provide a simple illustration of the benefits of lab-based RtD (Jonsson et al. 2005). While designers of automotive speech systems have numerous variables to consider – the gender of the car voice, the volume, the content of the messages, the

urgency, the effects on product safety, cost, likability, etc. – Jonsson’s experiment narrowed the focus to examine how the emotion and energy level of the in-car voice system affected drivers in a driving simulation. The experiment found that drivers who interacted with voices that matched their own emotional state drove better and communicated more than drivers interacting with mismatched emotions. This type of experiment produced implications for the design of new in-car voice services, a feat that would be difficult, unsafe and expensive to recreate in field settings. It also provided benefits outside of the product-design process by contributing to theory about emotional state in voice response systems.

Unlike conventional lab experimentation, design researchers are not strictly confined to isolating specific variables. Because of the exploratory nature of design research, researchers typically modify a number of design features prior to narrowing down to a critical few. In RtD, designs may vary by a large or small degree. This degree of variation determines how precisely a researcher can claim causal factors. For example, if a new design includes seven new distinct design concepts and performs 10 percent better than the prior design, one cannot know exactly which features are most salient. However, this bucket approach manages to both explore broad possibilities and demonstrate an effect. Through further iteration and experimentation, the design researcher can narrow the variation between prototypes and make stronger claims about the casual factors.

Field

In field-based RtD, researchers place designs into an everyday context to study how people interpret, create meaning and behave around these new artifacts. Placing prototypes into the field helps the researcher contextualize how individuals and groups live with and make sense of new artifacts in ways that would be difficult to do in lab settings. As

Comment [SN3]:
Please check if the author names in Reference are correct.



Figure 18.5 Ju and Sirkin's 'waving hand' kiosk explored greeting dynamics in public settings.

Gaver et al. articulated 'we don't emphasize precise analyses or carefully controlled methodologies; instead, we concentrate on aesthetic control, the cultural implications of our designs, and ways to open new spaces for design' (Gaver, 1999). By placing designs in context, design researchers can generate theory by reflecting on observations of use.

The deployment of novel prototypes into real-world environments allows researchers to understand how people naturally react to artifacts in a particular environment. For example, Ju and Sirkin placed an interactive kiosk with a waving hand into various quasi-public locations, like the entranceway of a bookstore or the lobby of a computer science building (Ju & Sirkin 2010) (see Figure 18.5). The contextual nature of the interaction makes the field a natural choice for the study's location. The experiment had to be designed around the vagaries of uncontrolled settings – for example, the fact that people do not just walk around alone, but often in dyads and groups. It also allowed researchers to see how people in dyads and larger groups interact with a design object differently than individuals alone.

Field-based research through design bears resemblance to action research (also called participatory action research) where a group of stakeholders make deliberate changes to a system in order to simultaneously address a problem situation and further the goals of social science (Gilmore et al. 1986). Kurt Lewin first described action research as 'comparative research on the conditions and effects of various forms of social action' (Lewin 1946). Both design researchers and action researchers can iteratively create changes and observe the effects of those changes, towards the goal of social transformation.

Exhibition

Exhibition-based research follows from traditions in art and design, rather than from natural, physical or social science. The place for conducting this style of RtD is not the laboratory or a field site, but a venue for public engagement, such as museums, showroom floors, or even well-trafficked websites. Here, the designer researcher's goal is to use designed artifacts to express ideas and to instigate public discourse. Such design researchers often draw intellectual inspiration

Comment [RC4]:
Is this Gaver et al. 1999? Give page number for quote?

Comment [SD5]:
I can look it up if necessary.

Comment [SD6]:
Can lookup if necessary.

Comment [RC7]:
Give page number for quote?

from historically important artistic movements like constructivism, surrealism, romanticism, classicism, expressionism, or minimalism (Arnason & Mansfield 2009).

Tony Dunne and Fiona Raby from the Royal College of Art explicitly use design to provoke discussion about the implications of emerging technologies (Dunne 2011). In their 2005 project, Evidence Dolls, Dunne and Raby created a set of special dolls to explore perspectives on genetics (see Figure 18.6). These hypothetical products were intended to spark public debate on issues such as designer babies, desirable genes, mating logic and DNA theft (Dunne & Raby 2005). Their concepts were not tested empirically per se, but were intended to trigger thoughts and discussions among their audience. As Dunne articulated, ‘new ideas are tried out in the imagination of visitors, who are encouraged to draw on their already well-developed skills as window-shopper and high-street showroom-frequenter’ (Dunne 2006). By placing their tangible designs in a public exhibition setting, design researchers tap into the conscious, reflective and critical public eye.

Comment
{SD8}:
Can-lookup
if-necessary:

Comment
{RC9}:
Give-page
number-for
quote?

Research intended for public exhibition is judged by different standards than RtD in the lab or field. In order to be successful, exhibited artifacts need to engage an audience and effectively communicate an idea. In other words, the community at large judges the validity and impact of exhibition-based RtD. This impact can be measured, for example, through the size of the audience, the number of public comments, the amount of traffic to a website, or the aggregate qualitative sentiment of critics. Further, the possibility of reaching a large audience serves as one motivator for exhibition-based researchers (Hustwit 2009).

Our concept of ‘place’ in research through design does not imply a particular philosophical stance. We intentionally separate the methodological concerns of the research setting from the philosophical stance imposed on design artifacts (see ‘point-of-view’ below). This distinction is notably different from Koskinen and colleague’s concept of showroom-based RtD, where designers apply critical theory and pragmatist philosophy and introduce artifacts to galleries and public



Figure 18.6 Dunne and Raby’s ‘Evidence Dolls’ challenged exhibition visitors to think about the future of genetic engineering (photo: Kristof Vrancken).

settings in order to make a cultural or political statement (Koskinen et al. 2011). To give our framework more flexibility, we make a deliberate distinction between placement and the philosophical stance. In our view, research through design has the potential to adopt any philosophical stance in any research setting.

Point-of-View

A third dimension of Research through Design is *point-of-view* – the design researcher’s philosophical perspective on a subject matter. While traditional scientists are expected to be as objective as possible, design researchers explicitly put forth a point-of-view, a subjective argument about the future. A novel perspective can add valuable new insights into the interpretation of a design space. Although this is not intended to be a comprehensive list, we discuss several prevailing points-of-view within HCI design research:

Pragmatic perspectives	focus on the identification and resolution of common and everyday needs encountered by people in their day-to-day lives;
Utopian perspectives	present an idealized vision of a possible future centered around some trend, artifact or service; and
Critical perspectives	call attention to the complications or possible dystopian outcomes of possible futures.

Through point-of-view, design researchers impose a philosophy, which in turn, affects the holistic user experience, not only towards the interface, but towards the perception of the whole project. Differing points-of-view can often result in significantly different prototypes of similar technologies. For example, in the domain of robot design, some researchers and designers focus on pragmatic issues, such as understanding how people read and react to various humanoid robots so that they can make them more pleasing to people (Nomura et al. 2007). Others take a more critical perspective, for example examining the basic assumption that robots could or

should look like people (Hoffman 2007). Both of these are different to the utopian perspective – often promulgated by TV series like *Star Trek: The Next Generation* – that robots will look and act just like other human beings. Opposing viewpoints serve to calibrate the community to address societal needs and to avoid undesired consequences.

These three perspectives are not comprehensive, as there are many other points-of-view (e.g. political, ethical, anarchistic) that designers could impose on novel artifacts. In this section, we explain how designers influence research outcomes (sometimes unconsciously) by projecting their philosophy on designed objects. Hence, in RtD, research outcomes are as much a reflection of the designer as an indication of how people will react.

Pragmatic Perspectives

The pragmatic perspective in design research is characterized by a focus on addressing everyday problems or needs. This perspective has roots in human factors and industrial design, where designers and researchers look for ways to fix problems imposed by newly engineered systems. Sometimes these problems were psychological – for instance, the well-known industrial designer Henry Dreyfuss explored different ways of using design to make passengers feel comfortable in commercial airplanes, testing the use of plush upholstered seats and curtained windows so that people might feel like they were in a living room rather than hurtling through the air in a steel tube at thirty thousand feet (Dreyfuss 1955). Pragmatists may focus on resolving physical limitations, such as Mountford and North’s (1980) work on voice input to reduce pilot workload. Human-centered research methods – such as lab experiments and field studies – often help to either pinpoint problems or to evaluate possible solutions.

Some RtD focuses on exploring the pragmatic issues that will arise with impending technologies. For instance, Takayama et al. used online surveys to investigate how people

view the future role of robots (Takayama et al. 2011). The research team created video prototypes using animated robots that illustrated the designed interactions, allowing the team to probe factors – such as ‘performed’ forethought and reaction – that influence robot design before having to build any robots. Video prototypes may result in different reactions when realized in physical form, but they help reduce the number of possible designs to a reasonable subset that can be tested with higher-fidelity iterations.

Utopian Perspectives

Some design researchers make the case for new technologies or design directions by idealizing the broader implications of these directions. One classic HCI example is Doug Engelbart’s oNLine System (also known as ‘The Mother of All Demos’) (Englebart 1968). Engelbart and his colleagues at SRI developed a series of interconnected technologies with the purpose of ‘augmenting human intellect’. This radical demo included prototypical designs for the computer mouse, video collaboration, hypertext and copy-paste (see Figure 18.7). This utopian perspective

promoted the then-unusual idea that computers should be used to help humans to perform work, rather than to perform work for them.

Similarly, Apple’s Knowledge Navigator video also embodies this utopian vision of technology (Dubberly 2007). This video depicts a college professor in his office, interacting with a tablet device with an intelligent agent that helps him manage his schedule, research information, and communicate with other researchers (see Figure 18.8). The work presents a utopian vision of a future in which computing and communication technologies allow people to interact rapidly with people and data. Great vision designs are like movies and novels – they need to achieve resonance with a fairly wide audience to make a difference. With this broad impact comes critique and discussion. For instance, many people critique Knowledge Navigator’s magical portrayal of technology. The system’s speech recognition, artificial intelligence and video networking work seamlessly, and, as a result, it gave some future users and designers a false impression of what is possible.



Figure 18.7 Engelbart’s oNLine System demonstrated a vision of ‘augmenting human intellect’ that had a profound influence on the field of human–computer interaction (attributed to SRI International).



Figure 18.8 Apple's Knowledge Navigator video presented a utopian vision of how people could one day interact with intelligent agents.

Utopian perspectives get traction when accompanied by a concrete prototype (Schrage 1996). For example, the Tivoli/Liveboard project at Xerox PARC created a utopian vision of workplace meetings where a smart whiteboard not only enables people from remote sites to share a view of a common written space, but also enables groups to get rid of the mildly subservient 'notetaker' role (Moran et al. 1998; Pedersen et al. 1993). The systems sought to clarify the human-oriented value proposition well before the underlying technologies permitted these ideas to be tractable in the consumer market.

Critical Perspectives

Some design researchers take a critical perspective in order to instigate debate and reflection around design's unintentional and inadvertent consequences. Dunne and Raby, for example, use provocative point designs as a way of questioning assumptions promulgated by consumer culture (Dunne 2011). They created the *Technological Dream Series: No.1, Robots* to question the commonly held belief that someday robots will do everything for us. Their series featured 'robot' artifacts and videos of projected interactions

that explicitly rejected traditional notions of the robot, as portrayed by popular media, such as the Jetsons™. Their robots had little quirks and neuroses – human dependencies that reflected Dunne and Raby's skepticism over the capability or desirability of mainstream robots.

Similarly, Purpura and colleagues proposed a tongue-in-cheek system called *Fit4Life* as a critical response to the view that technology alone can persuade healthier behavior (Purpura et al. 2011). The authors describe a conglomeration of real technologies – including a food consumption sensor and a 'thinsert' to measure body weight through footwear – to monitor and persuade users to live healthier lives. The system is comprised entirely of plausible technology currently in development within the Ubicomp research community. However, when put together into a hyper sense-and-react system, the intervention seems absurd. Throughout most of the paper, the authors lead the reader to believe the system is real, only to later provoke reflection about values and politics of design in persuasive computing. Other critical approaches to design focus on how technology affects marginalized

groups, such as LeDantec's study of urban homeless people (Le Dantec & Edwards 2008) and diSalvo's efforts to engage local communities in policy discourse (Di Salvo and Lukens, 2009).

Because the goals of critical design are to provoke thought and reflection, design researchers often create new methods to capture these diverse interpretations. For instance, Sengers and Gaver employed the traditional lab-based method of Likert-scale ratings to evaluate their designs, but they encouraged study participants to label the anchors on each scale (Sengers & Gaver 2006). This unconventional tactic makes it difficult to compare study results. However, as they point out, the goal was not to show that their designs outperform reference designs, but to discover the values important to users and to question whether designers should be the arbiters of which values or metrics are used to judge designs.

DISCUSSION

Our framework for Research through Design illustrates the wide range of activities undertaken by researchers that utilize design, and illuminates how such diverse goals lead to different approaches. We hope our framework invites diversity and expands the definition of RtD, with an implicit goal of allowing more researchers to find a home under the RtD umbrella. Some design researchers may specialize within a particular combination of projection, place and point-of-view. Others may try different styles of RtD from project to project. However, it takes a community of researchers to explore all aspects of a design space and to construct time-honored theory.

How Communities of Design Researchers Explore Projection, Place, and Point-of-View

In the dimension of *projection*, the trajectory of the research is not uniform or smooth, but has the tendency to evolve in specific ways.

Research artifacts tend to progress from breakthroughs to point designs to patterns, and, in so doing, helps to discover, colonize and then systemize new arenas of design. Individuals may explore a particular design space through a portfolio of designs (Gaver 2012), but typically it takes an entire research community a long period of time to evolve from breakthroughs to principles.

In choosing a *place* for research through design, individual researchers can and often do use a multi-faceted strategy by undertaking different research methods (e.g. they start in the lab and then move to the field; or maybe they start on an exhibit floor and then test key variables in the lab). Design researchers often traverse locations in order to triangulate insights that are not evident from any one method or perspective alone. While the adoption of multiple disparate methods can open design researchers to charges of dilettantism, this strategy also allows researchers to find the methods that answer the questions they have, instead of answering just the questions that a particular method affords.

The fact that design researchers often depart from very different *points-of-view* performs a tremendous service for the design and research community as a whole. Within any domain, the ongoing debates between the utopians and critics, between the positivists and constructivists, between the pragmatists and visionaries, and so on, not only raise the intellectual bar, they serve to calibrate what kind of future we collectively desire. While each group often argues that their perspective warrants primacy, it is actually the dialectic effect of contrasting approaches that helps the community as a whole.

Assessing Research through Design

Research through design emphasizes future possibilities and results in theory that can guide design practice and reveal insights about people, culture or interactions. As the community of design researchers grows, there has been increasing call to clarify expectations

about the outcomes of RtD (Gaver 2012; Zimmerman et al. 2010). Gaver has highlighted how RtD is intended to be ‘provisional, contingent and aspirational’, and hence, does not necessarily need to abide by standards, protocols and specific guidelines (Gaver 2012). Reflecting on our framework and the growing body of literature on RtD, we have compiled a list of qualities to consider when conducting RtD and when judging papers that conduct RtD. In our view, ‘good’ research through design strives to embody one or more of these qualities:

- **Predictive:** the design researcher makes some kind of conjecture about the future through the creation of design artifacts;
- **Relevant:** the designed artifacts and theory-generation speak to larger social concerns that are either pertinent now or will be in the future;
- **Novel:** the designed artifacts are not facsimiles, but original and unique designs;
- **Fruitful:** the designed artifacts yield valuable data and provide fodder for theory-building;
- **Suitable:** the design research chooses data gathering methods that are appropriate and consistent for the chosen setting;
- **Reflexive:** the design researcher acknowledges their philosophical stance and reflects on how the point-of-view affects the audience reaction;
- **Aesthetic:** the design researcher creates artifacts with an intentional appearance and form.

Research *on* design and *for* design can help design researchers hone their abilities. For

example, design researchers can improve their craft through deliberate reflection (Schön, 1995), iterative prototyping (Dow et al. 2009) and parallel design (Dow et al. 2010) – practices currently advocated by professional designers. The framework outlined in this chapter seeks to help design researchers contemplate the range of methods and viewpoints and choose an approach that best helps them contribute to a body of knowledge.

CONCLUSION

In this paper, we discussed an array of research activities that use *design* as a key tool for developing theories about people, cultures and interactions. By characterizing how research through design varies with regard to *projection* into the future, *places* where the research occurs and *points-of-view* adopted by the design researchers, we hope to help rationalize and justify the variations, and to highlight the commonalities across different RtD activities. RtD sometimes borrows methods and techniques from traditional social science research or the fine arts. However, since research through design is distinct in purpose from traditional epistemologies, it needs to be evaluated on its own merits. Within our framework, we provided exemplars of different kinds of RtD and discussed how each serves its intended goals.

Case Study: A Research through Design Perspective on the Evolution of Telepresence

Every novel design space begins with a few inspiring examples. These early examples lead to fast followers who continue to populate the space of ideas and discover unforeseen constraints and opportunities. Once enough designs enter the space, design researchers can reflect on them, describe key principles, and articulate a language for that particular design domain. This evolutionary process is evident in a number of interactive systems.

Telepresence exemplifies how research through design traverses our framework. In 1980, Minsky coined the term to describe technologies that let people to feel present at a remote location (Minsky 1980). However, the original idea appeared much earlier, as a dystopian vision of the future: Chaplin’s 1934 film *Modern Times* shows the factory boss peering into the workers’ bathroom and Radford’s 1964 film *Nineteen Eighty-Four*

presents a chilling depiction of 'big brother' constantly monitoring citizens' daily lives. These films offered a critical perspective on telepresence without explaining how such technology might actually come to be.

The public's first contact with a working telepresence technology was Bell Laboratories' Picturephone at the 1964 Seattle World's Fair (see Figure 18. A). Callers could sit in telephone booths with small monitors and have a video-based conversation with a stranger in another booth. The Picturephone represented a breakthrough design intended to transform communication in daily life. Ahead of its time, the Picturephone was discontinued by 1970. In 1968, Douglas Englebart's oNLine System demonstrated remote collaboration in a utopian view of interactive computing and also represented an early breakthrough in the evolution of telepresence (Englebart 1968).



Figure 18.A An advertisement for the Bell Picturephone (developed at Bell Laboratories, a subsidiary of Alcatel-Lucent).

Another early inspiration for telepresence came from the art world, with Galloway and Rabinowitz 's 1980 project, "Hole in Space", a 'public communication sculpture' where two wall-sized video displays connected public sites in New York and Los Angeles (Galloway & Rabinowitz 1980). People on the street could see life-sized images of strangers in the other city, as well as hear and speak with them. The exhibition was a point design that expanded the design space to crowd-to-crowd, rather than only person-to-person interaction. By the late 1980's, researchers Xerox PARC, EuroPARC and the University of Toronto began a systematic exploration telepresence with each lab creating multiple point designs to address specific remote communication issues, such as always-on casual video connections between offices (Gaver et al. 1992; Buxton 1992) and time-shifted telepresence between locations in the US and Europe (Dourish & Bly 1992). Similarly, Paulos' *Personal Roving Presence* project experimented with embedding telepresence technologies into a physical robot form (Paulos & Canny 1998), and provided an early precedent to modern research on embodied social proxies (Venolia et al. 2010) (see Figure 18.B). The community's portfolio of designs highlighted diverse design dimensions, exposed design opportunities, and explored the benefits and disadvantages of telepresence.

(Continued)

(Continued)

Figure 18.B Paulos's 'Personal Roving Presence' (PROP) embedded telepresence technology atop a physical rover.

With sufficient point design exploration, research through design within this domain could focus on understanding how key variables affect the human experience of telepresence. Olson and Olson examined face-to-face collaboration to enumerate key characteristics that an ideal telepresence system would have to support communication, such as rapid feedback, immediate corrections, multiple communication channels and shared local context (Olson & Olson 2000). Hollan and Stronetta push back against the always-on face-to-face inevitability of telepresence to suggest there are objectives "beyond being there" that would suggest lower cost, more ephemeral, more anonymous forms of telepresence (Hollan & Stronetta 1992). Extending this notion, Carroll et al. (2006) explored how to support activity awareness that transcends moment-to-moment social interaction, providing both co-located and remote collaborators a "common ground" to enhance understanding of each other's activities.

Through diverse projections, places, and points of view, design researchers have shaped what telepresence technology has become today. Some of the earliest projections into the future, such as videophones and large collaborative wall displays (e.g., Cisco, Polycom, Skype, WebMeeting, etc.), are becoming commonplace, while other visions, like the Star Trek *Holodeck*, are starting to be explored in research labs (Dow et al. 2007). Because these new telepresence technologies are ubiquitous, researchers can more easily evaluate design alternatives in lab and field settings, and designers can more readily incorporate telepresence technologies as part of their public exhibitions. Finally, we continue to see contrasting points-of-view, from utopian visions that appear in marketing campaigns, to dystopian warnings in feature films, to pragmatic analyses that lead to more carefully refined and useful telepresence products.

REFERENCES

- Alexander, C., Ishikawa, S. & Silverstein, M. (1977) *A Pattern Language: Towns, Buildings, Construction*, Oxford University Press.
- Arnason, H.H. & Mansfield, E.C. (2009) *History of Modern Art* 6th ed., Prentice Hall.
- Axelrod, R., 1997. Advancing the art of simulation in the social sciences. *Complexity*, 3(2), pp.16–22.
- Beaudouin-lafon, M. & Mackay, W. (2002) Prototyping Tools and Techniques. In *Human-Computer Interaction Handbook*. L. Erlbaum Associates Inc., p. Pages 1006–1031.
- Bishop, D. (1992) *Marble Answer Machine*. Royal College of Art.
- Buxton, B. (2007) *Sketching User Experiences: Getting the Design Right and the Right Design*, Morgan Kaufmann.
- Buxton, W.A.S. (1992) Telepresence: integrating shared task and person spaces. *Proceedings of the conference on Graphics interface 92*, (1992), pp.123–129.
- Card, S. (1996) Pioneers and settlers: methods used in successful user interface design. In *Human-Computer Interaction Design: Success Stories, Emerging Methods and Real-World Context*. M. Rudisill, C. Lewis, R. Poison, & T. McKay (eds.). Morgan Kaufmann, San Francisco.
- Carroll, J.M. & Kellogg, W.A. (1989) Artifact as theory-nexus: hermeneutics meets theory-based design. *SIGCHI Bull.*, 20(SI), pp.7–14.
- Copi, I.M. & Cohen, C. (2005) *Introduction to Logic* 12th ed., Pearson Education, Inc.
- Creswell, J.W. & Clark, D.V.L.P. (2006) *Designing and Conducting Mixed Methods Research* 1st ed., Sage Publications, Inc.
- Le Dantec, C.A. & Edwards, W.K. (2008) Designs on dignity. In *Proceeding of the twenty-sixth annual CHI conference on Human factors in computing systems*. Proceeding of the twenty-sixth annual CHI conference. Florence, Italy.
- Davidoff, S. et al. (2007) Rapidly Exploring Application Design Through Speed Dating. *Proceedings of Ubicomp*.
- DiSalvo, C. & Lukens, J. (2009) Towards a Critical Technological Fluency: The Confluence of Speculative Design and Community Technology Programs. In *Proceedings of Digital Arts and Culture Conference*.
- Dourish, P. (2006) Implications for design. In *Proceedings of the SIGCHI conference on Human Factors in computing systems*. the SIGCHI conference. Montreal, Quebec, Canada.
- Dourish, P. & Bly, S. (1992) Portholes: Supporting Awareness in a Distributed Group Work. *Computing*, pp.541–547.
- Dow, S. (2011) How prototyping practices affect design results. *interactions*, 18(3), p.54.
- Dow, S. et al. (2010) Parallel Prototyping Leads to Better Design Results, More Divergence, and Increased Self-Efficacy. *Transactions on Computer-Human Interaction*, 4.
- Dow, S. et al. (2007) Presence and engagement in an interactive drama. In *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems*. San Jose, California, USA, pp. 1475–1484.
- Dow, S. et al. (2005) Wizard of Oz Support throughout an Iterative Design Process. *IEEE Pervasive Computing*, 4(4), pp.18–26.
- Dow, S.P. et al. (2011) Prototyping Dynamics: Sharing Multiple Designs Improves Exploration, Group Rapport, and Results. In *Conf on Human Factors in Computing Systems*.
- Dow, S.P., Heddlestone, K. & Klemmer, S.R. (2009) The Efficacy of Prototyping Under Time Constraints. In *Proceeding of ACM Conference on Creativity and Cognition*. Berkeley, California, USA: ACM, pp. 165–174.
- Dreyfuss, H. (1955) *Designing for People* First Printing., Simon & Schuster.
- Dubberly, H. (2007) The Making of Knowledge Navigator. In *Sketching User Experiences*. B. Buxton. Morgan Kaufmann.
- Dunne, A. (2006) *Hertzian Tales: Electronic Products, Aesthetic Experience, and Critical Design*, The MIT Press.
- Dunne, T. (2011) Dunne & Raby papers. Available at: <http://www.dunneandraby.co.uk/content/bydandr>.
- Dunne, T. & Raby, F. (2005) Evidence Dolls. Available at: <http://www.dunneandraby.co.uk/content/projects/69/0>.
- Duyn, D.K. van, Landay, J.A. & Hong, J.I. (2006) *The Design of Sites: Patterns for Creating Winning Web Sites* 2nd ed., Prentice Hall.
- Englebart, D.C. (1968) oN-Line System. Available at: [http://en.wikipedia.org/wiki/NLS_\(computer_system\)](http://en.wikipedia.org/wiki/NLS_(computer_system)).
- Fallman, D. (2003). Design-oriented human-computer interaction. In *Proceedings of the conference on Human factors in computing systems*. the conference. Ft. Lauderdale, Florida, USA, p. 225.
- Forlizzi, J., Zimmerman, J. & Stolterman, E. (2009) From Design Research to Theory: Evidence of a Maturing Field. In *Proceedings of the International Association of Societies of Design Research*.
- Frayling, C. (1993). Research in Art and Design. *Royal College of Art Research Papers*, 1, pp.1–5.

- Frens, J.W. (2006). *Designing for Rich Interaction: Integrating Form, Interaction, and Function*. Eindhoven, the Netherlands: Department of Industrial Design.
- Galloway, K. & Rabinowitz, S. (1980). *Hole in Space*. Santa Monica, California: Mobile image videotape.
- Gaver, W. et al. (1992). Realizing a video environment: EuroPARC's RAVE system. *Proceedings of the ACM Conference on Human Factors in Computing Systems*, p.27.
- Gaver, W. et al. (2004) The drift table: designing for ludic engagement. In *extended abstracts on Human factors in Computing Systems*. CHI 2004. New York, NY, USA: ACM, pp. 885–900.
- Gaver, W. (2012) What should we expect from research through design? In *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems*. CHI '12. New York, NY, USA: ACM, pp. 937–946. Available at: <http://doi.acm.org/10.1145/2207676.2208538> [Accessed June 19, 2012].
- Gaver, W., Beaver, J. & Benford, S. (2003) Ambiguity as a resource for design. In *Proceedings of the SIGCHI conference on Human factors in computing systems*. Ft. Lauderdale, Florida, USA: ACM, pp. 233–240.
- Gaver, W., Dunne, T. & Pacenti, E. (1999) Design: Cultural probes. *interactions*, 6(1), pp.21–29.
- Geertz, C. (1977) *The Interpretation Of Cultures*, Basic Books.
- Gilmore, T., Ramirez, R. & Krantz, J. (1986). Action-Based Modes of Inquiry and the Host-Researcher Relationship. *Consultation*, 5(3).
- Greenberg, S. & Buxton, B. (2008) Usability evaluation considered harmful (some of the time). In *Proceeding of the twenty-sixth annual CHI conference on Human factors in computing systems*. Proceeding of the twenty-sixth annual CHI conference. Florence, Italy, p. 111.
- Hoffman, G. (2007) *On Non-Humanoid Expressive Robots*. Ensemble: Fluency and Embodiment for Robots Acting with Humans. MIT Thesis.
- Hollan, J., Hutchins, E. & Kirsh, D. (2000) Distributed cognition: toward a new foundation for human-computer interaction research. *ACM Trans. Comput.-Hum. Interact.*, 7(2), pp.174–196.
- Hollan, J. & Stornetta, S. (1992) Beyond being there. In *Proceedings of the SIGCHI conference on Human factors in computing systems*. the SIGCHI conference. Monterey, California, United States.
- Hustwit, G. (2009) *Objectified* (Documentary film).
- Ishii, H., Mazalek, A. & Lee, J. (2001) Bottles as a minimal interface to access digital information. In *CHI extended abstracts on Human factors in computing systems*. CHI '01 extended abstracts. Seattle, Washington.
- Ishii, H. & Ullmer, B. (1997) Tangible bits. In *Proceedings of the SIGCHI conference on Human factors in computing systems*. the SIGCHI conference. Atlanta, Georgia, United States.
- Jonsson, I., Nass, C., Harris, H., Takayama, L. (2005) Matching in-Car Voice with Driver State: Impact on Attitude and Driving Performance. Stanford, CA: Stanford University.
- Ju, W. & Sirkin, D. (2010) Animate Objects: How Physical Motion Encourages Public Interaction. *Persuasive Technology*, pp.40–51.
- Ju, W. & Takayama, L. (2009). Approachability: How People Interpret Automatic Door Movement as Gesture. *International Journal of Design*, 3(2).
- Kelley, T. (2002) *The Art of Innovation*, Broadway Business.
- Klemmer, S.R. et al. (2001) The designers' outpost: a tangible interface for collaborative web site. In *Proceedings of the 14th annual ACM symposium on User interface software and technology*. Orlando, Florida: ACM, pp. 1–10.
- Kolko, J. (2011). Abductive Thinking and Sensemaking: The Drivers of Design Synthesis. *Design Issues*, 26(1), pp.15–28.
- Kolko, J. (2007) *Thoughts on Interaction Design*, Elsevier.
- Koskinen, I. et al. (2011) *Design Research Through Practice: From the Lab, Field, and Showroom*, Elsevier.
- Landay, J.A. & Borriello, G. (2003) Design patterns for ubiquitous computing. *Computer*, 36(8), pp.93–95.
- LeCompte, M.D. (1999). *Ethnographer's Toolkit: 7-volume paperback boxed set 1st ed.*, AltaMira Press.
- Lewin, K. (1946) Action Research and Minority Problems. *Journal of Social Issues*, 2(4), pp.34–46.
- Liao, C. et al. (2008) Papiercraft. *ACM Transactions on Computer-Human Interaction*, 14(4), pp.1–27.
- Mackay, W.E. et al. (1998) Reinventing the familiar. In *Proceedings of the SIGCHI conference on Human factors in computing systems*. Los Angeles, California, United States.
- Mackay, W.E. (1999) Is paper safer? The role of paper flight strips in air traffic control. *ACM Transactions Computer Human Interactions*, 6(4), pp.311–340.
- Mackay, W.E. & Fayard, A.-L. (1997) HCI, natural science and design. In *Proceedings of the conference on Designing interactive systems processes, practices, methods, and techniques*. Amsterdam, The Netherlands.
- Malinowski, B. (1984) *Argonauts of the Western Pacific*, Waveland Pr Inc.

- Martin, R.L. (2009) *The Design of Business: Why Design Thinking is the Next Competitive Advantage*, Harvard Business School Press.
- McCloud, S. (1993) *Understanding Comics: The Invisible Art*, Harper Paperbacks.
- Minsky, M. (1980) Telepresence. *Omni magazine*, (June).
- Moggridge, B. (2007) *Designing Interactions* 1st ed., The MIT Press.
- Moran, T.P., van Melle, W. & Chiu, P. (1998) Tailorable domain objects as meeting tools for an electronic whiteboard. In *Proceedings of the 1998 ACM conference on Computer supported cooperative work*. Seattle, Washington, United States.
- Nelson, H.G. & Stolterman, E. (2003) The design way: intentional change in an unpredictable world: foundations and fundamentals of design competence, Educational Technology.
- Nielsen, J. (1990) Ten Usabilities Heuristics. Available at: http://www.useit.com/papers/heuristic/heuristic_list.html.
- Nomura, T. et al. (2007) Implications on Humanoid Robots in Pedagogical Applications from Cross-Cultural Analysis between Japan, Korea, and the USA. In *The 16th IEEE International Symposium on Robot and Human interactive Communication*. pp. 1052–1057.
- Olson, G.M. & Olson, J.S. (2000) Distance matters. *Human Computer Interaction*, pp.139–179.
- Parnes, S.J. (1975) *Aha! insights into creative behavior* 1st ed., D.O.K. Publishers.
- Paulos, E. & Canny, J. (1998) PRoP. In *Proceedings of the SIGCHI conference on Human factors in computing systems*. the SIGCHI conference. Los Angeles, California, United States, pp. 296–303.
- Pedersen, E.R. et al. (1993) Tivoli. In *Proceedings of the SIGCHI conference on Human Factors in computing systems*. Amsterdam, The Netherlands.
- Peirce, C.S. (1998) *Collected Papers of Charles Sanders Peirce*, Thoemmes Continuum.
- Purpura, S. et al. (2011) Fit4life. In *Proceedings of the 2011 annual conference on Human factors in computing systems*. Vancouver, BC, Canada.
- Rode, J.A. (2011) Reflexivity in digital anthropology. In *Proceedings of the 2011 annual conference on Human factors in computing systems*. Vancouver, BC, Canada.
- Runkel, P.J. & McGrath, J. (1972) *Research on human behavior: A systematic guide to method*, Holt, Rinehart and Winston.
- Schon, D.A. (1995) *The Reflective Practitioner: How Professionals Think in Action*, Ashgate Publishing.
- Schrage, M. (1996) Cultures of prototyping. In *Bringing Design to Software*. T. Winograd (ed.). ACM Press, pp. 191–213.
- Sengers, P. & Gaver, B. (2006) Staying open to interpretation. In *Proceedings of the 6th ACM conference on Designing Interactive systems*. University Park, PA, USA.
- Simon, H.A. (1996) *The Sciences of the Artificial – 3rd Edition* 3rd ed., The MIT Press.
- Spool, J. et al. (1998) *Web Site Usability: A Designer's Guide* 1st ed., Morgan Kaufmann.
- Stangor, C. (2010) *Research Methods for the Behavioral Sciences* 4th ed., Wadsworth Publishing.
- Suchman, L. (1987) *Plans and Situated Actions*, Cambridge University Press.
- Takayama, L., Dooley, D. & Ju, W. (2011) Expressing thought. In *Proceedings of the 6th international conference on Human-robot interaction*. the 6th international conference. Lausanne, Switzerland, p. 69.
- Tohidi, M. et al. (2006) Getting the right design and the design right. In *Proceedings of the SIGCHI conference on Human Factors in computing systems*. Montréal, Québec, Canada: ACM.
- Truong, K.N., Hayes, G.R. & Abowd, G.D. (2006) Storyboarding. In *Proceedings of the 6th ACM conference on Designing Interactive systems*. University Park, PA, USA.
- Venolia, G. et al. (2010) Embodied social proxy. In *Proceedings of the 28th international conference on Human factors in computing systems*. Atlanta, Georgia, USA.
- Wellner, P. (1993) Interacting with paper on the DigitalDesk. *Communications of the ACM*, 36(7), pp.87–96.
- Wyche, S., Sengers, P. & Grinter, R.E. (2006) Historical Analysis: Using the Past to Design the Future. In *Proceedings of Ubiquitous Computing*, pp.35–51.
- Zimmerman, J., Forlizzi, J. & Evenson, S. (2007) Research through design as a method for interaction design research in HCI. In *Proceedings of the SIGCHI conference on Human factors in computing systems*. the SIGCHI conference. San Jose, California, USA.
- Zimmerman, J., Stolterman, E. & Forlizzi, J. (2010). An analysis and critique of Research through Design. In *Proceedings of the 8th ACM Conference on Designing Interactive Systems*. Aarhus, Denmark, p. 310.