2

Research Practices in Digital Design

Tone Bratteteig, Ina Wagner, Andrew Morrison,
Dagny Stuedahl, and Christina Mörtberg

In the twenty-first century, we are literally surrounded by digital things and things that turn out to be digital – or have some digital parts or are parts of a larger system in which there are digital elements. We carry around mobile phones and watches; many also have additional music players, PDAs or PCs. We live in houses filled with digital networks and artefacts; we depend on infrastructures that are partly digital and have digital systems attached to them; we use public and private services that are digital, are based on digital infrastructures and have other digital systems attached to them; and we experience embedded, ubiquitous computing as we live in digitally enhanced environments that support our activities with or without our conscious control. The digital layer(s) in the world constitute a real world.

Just as the diversity of digital things is so large, so too is design research varied. It includes a whole range of approaches that require skill and expertise, innovation and critical reflection. Inquiries into the use of digital work tools (Thoresen 1997; Gasser 1986) require different methods than investigating how teenagers shape their identities through text messaging (Ito 2003; Prøitz 2007). Studying the usability of a web site (Nielsen 1999), suggests a different approach than discussing what makes a social software application work successfully (see Chapter 7). Design of accounting systems is very different from designing ubiquitous environments for elderly people for home care. Variety and complexity are one of the main characteristics of digital design practices and their research. Digital design research embraces the diversity of design processes and products by inviting a greater variety of research about the digital. The design research in this book includes studies of design processes and products, people, and things, in which the digital play a crucial role. The analyses come from a broad range of disciplinary and interdisciplinary positions aiming to weave a braid that transcends the individual positions and to help us see the emerging changes.

We start our journey into practices in digital design research by describing our understandings of digital design and how we research these phenomena. Our aim is to communicate how and why a multidisciplinary approach is helpful for understanding and doing digital design. The chapter starts with four different stories from our own research, each of which illustrates aspects that we think

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are particularly salient for digital design research and points to new challenges for design as well as for the research. The section following these stories discusses more theoretically and methodologically digital design and digital design research.

Evolving Practices in Digital Design Research

Digital design is about making of digital artefacts in which the digital is a crucial characteristic. Focusing on the digital does not help us in limiting what things to include here: digital technology ranges from nanotechnology to large satellite infrastructure systems. The digital appears as representations and automata, and as instantaneously and ubiquitously distributed (see Chapter 5). Digital design hence refers to the planning and shaping of such digital representations, computer programs and distributed systems – but also to the shaping of visions about how these properties will be beneficial and important in our lives. Digital design is about the digital, but also about how the digital is embedded in our visions about a better life – as well as in the lived life of users.

The practices in digital design research are evolving as the elements of these practices change. Practices are not only what people do, and which objects are involved; we also need to understand the relations between people and objects in the processes of creating, communicating, knowing, and contextualizing involved in design and design research. In the following, we discuss aspects of design that we see as crucial to understanding digital design research practices: design as a collaborative activity that sometimes involves a large network of actors (client, investor, specialists of all sorts, and more); the multidisciplinarity of design work, which influences the ways designers express, represent, and communicate an evolving design concept; the role of artefacts and materials; the diversity of material practices which shape the design object, their historical-cultural roots and specificity; and the multiplicity of the design object itself, its changing representations in different media, and how it gets translated/transformed in the process of design.

This section presents four cases that tell about four different research practices in which digital design is an important element. They illuminate some of the challenges in digital design research that directly stem from new aspects of digital technologies and how these are translated as well as socially and culturally embedded.

Participatory Design of a Mobile Information Device

Most information systems are designed to be used by many users for different purposes, introducing the risk that those who register information are not the same people who make use of it, resulting in an uneven benefit from using the system and

producing poor data quality and frustrated users (Grudin 1988). The story in this section is about a successful multi-user system: an information system that allows patients to report their symptoms on a mobile device when entering the hospital, before consulting a doctor. The *Choice* system was a success, and the hospital wanted to develop a similar system for child patients. Children are, however, different from adults in several ways. For example, small children cannot read and write and do not understand abstract information well. A project was initiated, aimed at designing a '*children's Choice*' system for children with cancer (Ruland et al. 2006, 2007, 2008, Andersen et al. 2005). The project was considered a success, and children in the hospital now use the new system.

The story in this section aims to illustrate some of the challenges and difficulties in the process of designing the '*children's Choice*' system. We focus on some of the issues concerned with designing a multi-user system in which many different interest groups and their relations need to be handled so as to balance the benefits for the various users (see Grudin 1988). We particularly emphasize challenges concerned with the making of a participatory design (PD) process; here even participatory design with children (see Druin 1999a, b; Hutchinson et al. 2003; Iversen and Nielsen 2003; Dindler et al. 2005). The 'children's Choice' system had the additional challenge of having seriously ill children as their future users.

Fig. 2.1 Workshop with children designing the children's Choice (With permission from C. Ruland)

Participatory Design (PD) concerns ways of involving users in the designing of the artefact or system that they will (have to) use (cf. Chapter 1). The users provide knowledge that makes it easier to solve the right problem in the right way. Scandinavian PD acknowledges that users and user groups do not always agree on either problems or solutions, and emphasizes collaboration on developing and negotiating common design visions.

The *children's Choice* system was developed as a PD process, as the adult *Choice* system had been. The project management decided that the demands of the attention and time from the children with cancer could conflict with their illness and decided that children from a nearby school should represent them in the design process. Two groups of six children of 9 and 11 years, respectively, were engaged in the design project. They were picked up after school once a week and brought to the hospital for a 2-hour workshop, before being returned to school.

Each week included a participatory design workshops aimed at creating ideas for the design of the system and its interface. Each workshop had a theme and a goal set by the project leader, and the sequence of themes was designed to refine the design ideas and work out parts of the design visions in more detail. Each workshop included researchers, developers and a group of children. Up to three researchers watched and interacted with the children during the workshop, and each session was videotaped (which meant that there were almost as many adults as children in the workshops!).

In order to get the children to focus on representing very sick children, each workshop started with a scenario about a sick child – sick in a way that was possible for the children to identify with: breaking a leg, having the flu, falling down from a tree. The scenario ended with a task (design a start page, the main way of navigating, the vocabulary, etc.), and the children then went to work in a somewhat school-like way.

The first workshop was more of a warm-up exercise, but then there started a series of workshops focused on designing an information system that the hospitalized girl from the scenario would like to have. After an introductory scenario, the children sat together in groups drawing screen layouts, discussing what they would need to give information about (see Fig. 2.1).

Fig. 2.2 Suggestion for screen sequence using ready-made screen (With permission from C. Ruland)

The next two workshops followed up these design ideas. At this point, several screen layouts and screen elements drawn by a professional designer were brought to the table (Fig. 2.2 right). All the children took advantage of the ready-made figures

and included them in their designs, even replacing their own drawings with the ready-made ones (Fig. 2.2).

The ready-made suggestions were based on ideas and navigation metaphors that had been proposed by the children in the second workshop session, such as sailing from problem island to problem island, climbing in a tree where each branch is dedicated to a particular problem, or drawing a cartoon-like body where body parts could be revealed. The groups of children chose different starting points depending on their age (maturity level). The younger ones seemed to pick the figures they liked (e.g., pink and shiny), worrying less about the logic – or so it seemed to the adult observer. The older children were just as concerned about how they would feel – afraid or angry – as they were about symptoms like a hurting stomach. One of the girls knew a person with cancer, and her story and evaluations both contributed greatly to the design and added a sense of realism to the discussions, which was not present in the other groups.

Table 2.1 Suggestions for concepts for describing symptoms: adult categories and children's descriptions of symptoms fitting to those categories

Physical problem	Cry a lot (own suggestion)	Tired	Sleep during the day
	Bleed nose-blood		Easily tired
	Broken leg		Don't manage anything
	Wounds on the skin		Cannot read
Head pain	Head ache	Emotions	Afraid
	Dizzy		Nightmares
Vomiting	Pain in the belly		Embarrassed
	Vomit		Angry
	Nausea		Miss family and friends
	Phlegm in my mouth		Feel sorry
	Things smell bad/ unpleasant		Cry a lot
	Nose feels tight		Irritated
	Cough	Medication problems	Can't take my medicine
	Warm or sweat		Don't want to play with others
Mouth problems	Dry in the mouth		Shivering hands
	Pain in the mouth		Difficult to walk
	Don't manage to eat	Medication problems	Can't take my medicine
			Disgusting to take medicine

The fourth workshop did not add much to the designs, so the fifth workshop therefore moved on to conceptual design. The children were asked to help test and group translations of medical terms into terms that children would use to talk about their symptoms.

A list of terms had been suggested by the hospital researchers and written on post-it notes before the session. The discussion took place in front of a big sheet of paper on the wall. The categorization of the symptoms surprised the adult researchers

by the fact that the children mixed physical and emotional symptoms and did not make any distinction between the degrees of seriousness of the symptoms (Table 2.1) This categorization became an interesting occasion for discussing the children's experiences of being ill; between the children, as well as between the children and the researchers. It gave insight into a different logic concerned with the close relations between physical and emotional pain, and with a different way of sorting body parts and their symptoms.

The last workshop aimed at trying out a tablet computer prototype. The prototype was developed by Master students from the University of Oslo (Moe 2006; Sending 2006). The basic metaphor was a cage where the dinosaur Dino could get help from Dr. Spino (Fig. 2.3 right).

The prototype was not fully developed, but at least one path into the cage was ready to test. The children tested the prototypes in a hospital bed (Fig. 2.3, left and middle). The nurse researcher played a small scenario to help the child in the bed to play the role of a sick child and thus get a feeling for how the prototype would feel in a realistic setting.

Fig. 2.3 Testing the Dr. Spino prototype from a hospital bed (With permission from C. Ruland)

The children found the prototype interesting, but, having tried it in a bed, they decided that it seemed more like a toy than a system you would use to report serious problems. They also tried the *Choice* system (for adult patients), and concluded that they liked that one better, even if it was more difficult to understand.

Lying in bed and having a scenario played out by the bedside added seriousness to the children's discussions, which had not been there before, but for the input of the girl whose friend has cancer. The children felt that the user interaction should fit the situation, and that a game-like interface did not feel right in a hospital setting. However, from the position of a bed, they commented on features like weight and shape of the terminal that would be relevant in a real use situation.

The '*children's Choice*' system was further developed by hospital developers and tested on a group of employees' children, and on children with cancer (Moe 2006; Sending 2006). The system was finished and introduced as the *Sisom* system: 'si som' in Norwegian translates to 'tell as is' (Fig. 2.4). The system is now used in the hospital (Ruland 2008).

Fig. 2.4 The *Sisom* system: examples of pages (Images from www.rikshospitalet.no. With permission from C. Ruland)

The *Sisom* project illustrates several challenges to PD. Although the project explored a new area for a new type of technology – a mobile patient information system – the *Sisom* system needed to function as a work tool for the doctors and nurses. This double goal made it more difficult for the children as a weaker group to get their opinions heard in the design discussions. The question about which interests get to dominate the overall design is particularly tricky when several different interest group have to use the same system (Bjerknes and Bratteteig 1995). In the *Sisom* project the most important interest groups were children, nurses and medical doctors but doctors and children were represented through others. The tight structure of the *Sisom* project workshops contributed to giving the children a limited role in the design: the workshops acted as inspirational sources for the designers rather than as discussions opening up for very different design ideas. The children's ideas were fitted into a logic based in the profession of the information receivers. The children's choices were limited with respect to both the overall solution and the details of it – and even the setting of the problem to be solved. The doctors' and nurses' needs for information defined the scope of the project and therefore limited the possibilities for maintaining an openness in the design that enabled the (sick) children to discuss how they could communicate with doctors and nurses – or even others – by means of ICTs.

The *Sisom* project demonstrated that the concepts and logics of different interest groups may be very different: the translations and categorizations of medical health problems using child language and child logic revealed different interpretations of pain and of physical-psychological relations.

The different user groups exercised power with respect to the design process very differently. Children generally have a weak position as an interest group, particularly in a situation where medical doctors and nurses are allies in their interests in designing a good working tool. They also claim – like many other groups, e.g. cancer researchers, parents – to represent the children even better than they can do themselves in the design process. In addition, the healthy children were not really able to represent the sick children. The girl with a friend with cancer was the most empathetic. However, the children represented children very well and the experienced nurses and doctors used their knowledge to develop a 'persona' of a sick child (see Cooper 1999), and also arranged interviews with children who had recovered from cancer to test the system.

The *Sisom* project (like the *Choice* project) chose a mobile terminal as its information device. The mobile terminal seemed to have been chosen as a genre rather than from a wish to utilize the mobility of the device: the *Sisom* system is to be used in the hospital as information registration before seeing the doctor, at a particular place. However, a mobile system is useful not only when the user is mobile but also when the user is more or less immobile and cannot easily move to and from a stationary system. Even though mobile terminals have been around for many years, there are still a number of challenges in their design. Designing information services for mobile terminals must address challenges concerned with mobility: the terminal needs to be effortlessly moved – small, lightweight, powerful – and to be supported by an infrastructure that enables its operation. A mobile service is obviously a part of a larger system, and the system must work in order for it to add value to the service. The mobile terminal is often a personal device; when used in public places the distinction between private and public gets blurred. And the size of the mobile terminal poses severe constraints on the interaction, on input and output: the screen is small, any buttons need to be small – making them larger makes it necessary to introduce structure (hierarchical levels or modes) and hence new challenges for designing the presentation of that structural logic (Gutwin and Fedak 2004; Baudisch 2006; Moggridge 2007).

Participatory design is difficult to do (Bratteteig 2004a; Jansson 2007; Hardenborg 2007). In a hospital context it is easy to recognize that the many different users (workers and clients) have very different interests that may be difficult to balance or negotiate. It is also relatively easy to see how the technical systems are aligned with economics and legislation for the health-care sector, and also allied with medicine and medical professionals. The organization of work in health care is a result of earlier negotiations about distributions of tasks and power. Digital systems and artefacts may challenge this order – which makes digital design a political process – and add to the reasons for choosing PD approaches.

Involving children or other 'weak' groups (like elderly, physically handicapped) poses even more challenges to the participation and the representation of users (Marti 2006; Wu et al. 2004). Information systems that are being used for many purposes, by many different user groups, pose challenges as to who will have their logic represented in the overall design (Bjerknes and Bratteteig 1995; van der Velden et al. 2009). The complexity of the design increases as the system is public

and private, a tool and a toy, and even a part of the user's identity. Participatory design with 'difficult' users is particularly challenging: users who cannot make their own voice heard and users who speak for others – or claim to be speaking for others. Mobile terminals challenge information systems development by crossing social arenas (work, leisure, school) and therefore also represent a multitude of systems in one – in which the user may take very different roles (Kanstrup et al. 2008; Lee and Bichard 2008). Participatory design with a distributed community of users (Naghsh et al. 2008) poses further challenges to any ambitions to collaborate about design. Today, digital design is distributed and fragmented – as is participation in design (Bratteteig 2004b).

Designing Digital Environments

While the first example was about designing a game-like mobile application, the second example looks into novel interfaces, highlighting some challenges for interaction design. There is a growing interest in interfaces and interactions that involve all our senses, such as sound and tactile input/output, as well as material representations other than screens, like state-changes in objects similar to colour change in traffic lights. With their notion of 'ambient media', Ishii and Ullmer (1997) pioneered this development, designing for making invisible processes in the virtual world visible in the real world. Visible here means noticeable in an ambient way, through (changes of) light, sound, smell, and movement. Early examples were sound of rain, or water ripples projected onto the ceiling, representing the activity of a distant loved one; or 'active wallpaper' – patterns of illuminated projected patches – as indicators of low or high activity. In parallel, designers engaged in tangible interface designs that enable sound and motion interaction, based on gestural performances or physical objects (Ishii and Ullmer 1997; Ullmer and Ishii 2000; Larssen 2004; Loke et al. 2005). Further examples can be found in wearable computing (Farringdon et al. 1999), body-sensor networking (Yang 2006) and pervasive computing, including tracking of everyday interactions with wireless sensors (Tapia et al. 2004) and with RFID-tagged environments (Philipose et al. 2004). Ishii's weather bottles (Ishii et al. 2001) is a nice example of how the experiments with new technical possibilities for ways of interacting with a digital object can be utilized to address a new user: his mother – combining several different design research practices.

Design researchers as well as design practitioners have taken up the notion of embodied interaction introduced by Dourish (2001). The concept addresses how a situation must be considered as a whole. Meaning is created in the use of shared objects, and social interaction is related to how we engage in spaces and with artefacts. In this interplay the body has a central role; in many ways the body can be seen as the medium for 'having a world'. In this perspective Hornecker (2005) provides a definition of tangible interaction that expands human-computer interaction (HCI):

> Tangible interaction is not restricted to controlling digital data and includes tangible appliances or the remote control of real devices. Because it focuses on designing the interaction

> (instead of the interface), resulting systems tend less to imitate interaction with screen-based GUIs (as does placing and moving tokens) and exploit the richness of embodied action […]. Interaction with 'interactive spaces' by walking on sensorized floors or by simply moving in space further extends our perspective on 'tangible' interaction (Hornecker 2005: 225).

This aspect of embodied interaction is gaining relevance in view of attempts of using tangible computing or mixed reality for art and entertainment (Benford et al. 2006; Hämäläinen et al. 2005), in work and educational settings (Bannon et al. 2005; Ciolfi and Bannon 2005), as well as in urban renewal (Maquil et al. 2007). Multimodal interfaces are designed in fields as varied as dance performance, art installations, urban planning, and 3D worlds. Novel applications embed monitoring in interactive and engaging artefacts designed for recreational, tangible, and affective interaction.

The novel interfaces that emerge in the framework of embodied interaction pose challenges for interaction design, on the conceptual and technical level. Although the term 'interactive' is debated with respect to the role of the computer system as an active partner in the interaction (Jensen 1998), it becomes meaningful if we reserve it for the design of options for human activity when it becomes interwoven with technology. This requires developing sensitivities to issues such as the choice of material, enabling embodied interaction, facilitating collaboration, rich and easily understandable interaction, and so forth. The more so, as means of interaction have been extended from classical devices to gestures, body movements, and physical objects (tokens). Interaction is understood as a process with experienced qualities, embedded in social and cultural contexts. In the foreground is not the interaction itself (its technicality) but how to design the interaction (how to, for example, integrate movement and touch), as well as to design interaction styles (expressivity, diversity) before designing the product itself. The challenges involved in designing interactions include the selection of material, as its emotional significance and symbolism is relevant for how people interact with it; as are the aesthetics and economy of movement (Oritsland and Buur 2000). Interaction design has strong aesthetic and emotional, experience-based aspects: 'A user may choose to work with a product despite it being difficult to use, because it is challenging, seductive, playful, surprising, memorable or rewarding, resulting in enjoyment of the experience' (Djajadiningrat et al. 2000: 132).

Tangible user interfaces are among the novel digital designs attracting the attention of designers and researchers, but very few applications have been designed with a view on real life work situations. Some of the challenges connected to designing tangible user interfaces are highlighted by Maquil et al. (2007, 2008). They describe a tangible user interface – the *ColorTable* – designed to support groups of urban planners and diverse stakeholders in collaboratively envisioning urban change, using a set of mixed-reality technologies. Among the challenges were: how to support users in the collaborative creation of mixed-reality configurations; how to make use of material and spatial properties in designing both, physical interface, as well as multiple and simultaneous interactions; how to handle the complexity of urban projects while keeping interfaces and interactions simple and transparent.

The *ColorTable* is set up in the centre of the mixed reality tent (The MR-Tent) and provides a bird's eye view of the site. It presents a collaborative planning and discussion space – users are motivated to share their ideas and visions by moving coloured tokens of different shapes and colours on the table. The tangible user interface uses computer vision-based tracking from an overhead camera to detect the positions, shapes, colours and sizes of the objects on the table. Users can move and turn existing objects, while an overhead video projection onto the table provides interactive feedback. This table view is composed of several layers, combining real and virtual elements, forming a common interaction space. A physical map representing the urban site is placed on the table to define the scale of the interaction. For the workshop we prepared two maps of different scales that can be exchanged.

The *ColorTable* uses multiple interactive views to convey and encourage the urban design process. Inside the MR Tent, two large screens show perspective views of the urban site. The views are alternatively fed by a live video stream from a remote controlled camera, a panorama image prepared previously, and a direct view seen through a half transparent screen. These vertical screens show perspective views as seen by a pedestrian, while the horizontal surface (table) shows an overhead view inspired by maps. In order to navigate within the panorama, users can change the orientation of the viewpoint with a rotating disk (Fig. 2.5).

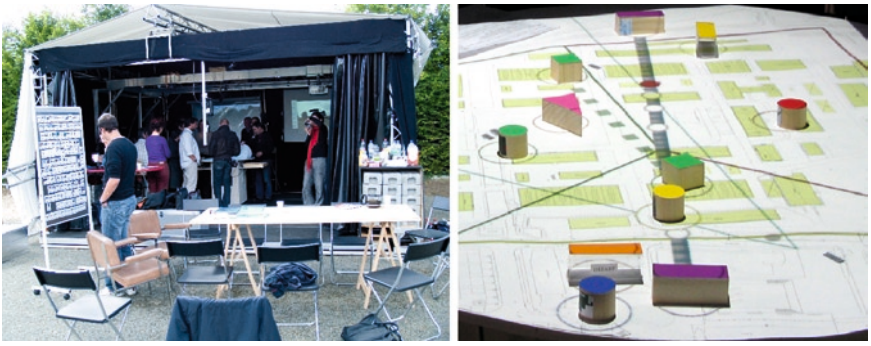

Fig. 2.5 Overview of *ColorTable* application

This is a rather complex set-up that combines different material, virtual and spatial components:

- A round table with physical maps of different scale and a set of tokens, as well as projected traces of participants' interventions (rectangles for objects, moving dots along paths for flows).
- Tokens of different size, shape, material and colour representing different visual and sound content, as well as activities, such as setting paths, defining land use, moving the hearing position, and erasing.
- 'Content cards' with a thumbnail of the visual object, whether it is a 2D or a 3D object, information on associated sound files, and barcode.

- A multi-layered interaction space consisting of a tent mounted on the site of an urban project, round table and two projection screens showing the constructed scene against the backgrounds.

The *ColorTable* went through several cycles of evaluation-feedback-redesign (and is still work-in-progress), which were organized in the form of participatory workshops in the context of real urban planning projects, with architect-planners and other specialists as well as concerned citizens as participants.

Fig. 2.6 Creating mixed reality scenes (here seen in the video-augmented view) through manipulating objects, gesturing, and talking

Working with the *ColorTable* illustrates embodied interaction (cf. Dourish 2001): through gesturing, placing tokens, rotating the table or sketching on the projection screen, participants 'perform' a mixed reality configuration, emphasizing particular interventions, and bringing an expressive element into a scene (Fig. 2.6, left). We could see how the size and shape of the table are relevant. A large working space encourages or even enforces collaboration since there is no way for a single person to manipulate all objects (Patten and Ishii 2000; Stanton et al. 2001). We observed how the round shape of the table, together with the possibility of rotating the viewpoint, was highly conducive to people gathering around and interacting. Also the spatial arrangement of table and the associated workspaces is crucial for collaboration to happen smoothly. In general, all the material and devices needed should be within reach but not in the way.

The size and materiality (haptic quality) of the colour objects clearly influences the way participants interacted with them and how they actively engage in building a scene. As one of the participants in one of the workshops we organized expressed it: 'I have the impression that everyone has their own object placed on the table and everyone identifies himself with his colour and his bench, and I have the impression that all of us negotiate projecting ourselves into the object'.

What we observed is a good example of haptic directness (Fig. 2.7). Haptic directness provides an isomorphism between manipulation and result (Hornecker and Buur 2006): we can watch the effects of our activities while performing

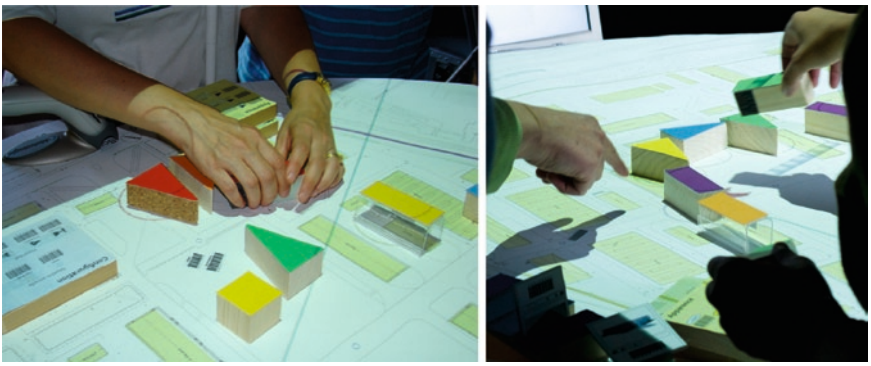

Fig. 2.7 Haptic directness – handling colour tokens

them – it enables simultaneous interaction. The colour objects are easy to understand, invite participation, and are sufficiently neutral so as not to privilege particular perspectives on an urban project. Expert and non-expert users can use them alike. We could also see that the context of urban planning poses specific requirements concerning spatial interaction. Users perform embodied interactions in several dimensions – placing colour objects on the paper map, switching viewpoint and panorama, and at the same time viewing the changes on the projection screen. Mapping these distributed interactions in different scales is a complex task.

Tangible user interfaces as part of new digital designs offer attractive solutions, in particular for collaboratives of users performing tasks or small projects in an expressive way. In her analysis of tangible user interfaces, Hornecker (2005) presents a framework for encouraging collaboration through tangible manipulation, spatial interaction, embodied facilitation, and expressive representation. Hornecker talks of embodied constraints as subtly leading users to collaborate. Our results agree with her experience that 'seemingly trivial design decisions (such as system size, placement and number of tools) had a huge impact on group behaviour, session dynamic and atmosphere' (Hornecker 2004). Moreover, there is a rich repertoire of forms, objects, spatial configurations, and materials to select from in tangible user interface design. These almost limitless possibilities pose conceptual problems, requiring designers to carefully analyse and constrain, so as to make the design harmonize with the ecologies of space, materials, devices, and people and to keep interactions simple and transparent.

In designing for physical interaction, particular attention has to be paid to the fact that the language of form is expanded to three dimensions and to a wider range of physical expressions (movement, gesture). This influences the ways meaning is generated and experienced in the interplay between ideas, physical interactions, and their mixed-reality expressions. Designing for tangible interactions needs to include design experiments as a part of the research.

This example illustrates the need for, and the challenges of, supporting embodied interactions that make use of material objects within physical space. Designing a

tangible user interface has the potential for creating a richer interaction experience, incorporating emotional expression in tangible interaction (Ross and Keyson 2007). Larssen et al. (2006) have analysed the *feel dimension* of technology interactions, referring to the work of Merleau-Ponty (1962). They describe tangible interaction 'as a particular kind of dialogue between bodies and things'. Brown and Duguid (1994) have emphasized the role of material features, in their peripheral, evocative, and referential function, as providing border resources for interaction. Jacucci and Wagner (2007) have studied how materiality is part of performative action.

We can also read this example as a story about performing design research while engaging in design. Research was tightly interwoven with design, as observing and analysing users' interactions with the tangible user interface, the mixed-reality scenes they co-constructed and debated, directly fed back into the design process. This exchange between research and design did not only bring novel ideas and pointed to opportunities for design changes; concepts offered by researchers were turned into reflective tools in the hand of designers (Maquil et al. 2008).

Communication Design

Information and Communication Technologies (ICTs) have been widely applied in contexts of technology-enhanced leisure and social interaction, as well as in those centred on learning and work. With respect to digital design practices and related research, however, *communication design* and research into the *design of communication* have received more oblique attention.

As the label communication design suggests, it is communication that is at the core of the practices and study of digitally mediated meaning making. Communication design (Mansell and Silverstone 1996; Frascara 2004; Morrison 2010) acknowledges that what characterizes human communication is its dialogical, situated and dynamic character. This character is realised through the interplay of tools and signs with technical and cultural resources (e.g. Bødker and Andersen 2005; Jenkins 2006). Together these depend on and are constituted by a complex mix of relations (Thackara 2005) between information systems design, media and their joint mediation through our situated actions. This is to reconceptualize some of the earlier relations in 'interaction' design (Poppenpohl 2006). In terms of exploring design research and practices, these relations are ones that are concerned with the socio-cultural, semiotic, aesthetic and participative (see Chapter 3). Communication design is complementary to approaches to interaction design that originate in HCI but that are motivated less by the earlier functionalism of such research and more by user and context rich exploration and development (Ehn and Löwgren 2003; Löwgren and Stolterman 2004; Fallman 2008; Skjulstad 2007a). In communication design, humanistic, social science and informatics, perspectives may be woven together in the design of artefacts and environments for communicative use and engagement. Also central is the acknowledgement that digital technologies are an increasingly crucial part of our daily, mediated communication. Conceptualizing

moves between practices of design and analysis involve concepts of metadesign (Giaccardi and Fischer 2008) and of mediated meaning making and the explorative and emergent nature of creativity on digital design (Morrison in press).

Such communication is a dynamic of different modes of expression and articulation that are conducted in a medley of media through our situated practices. The ways digital technologies are taken up in our professional, personal and popular cultural contexts may also help extend repertoires for design. Attention to the interplay of practice and theory in graphic design, for example concerning designers' portfolios on the web (Skjulstad 2007b), is one area that has begun to be developed in digital design. Conceptually, the practices of communication design need to take into account the relationships between human and machinic actors. This extends also to the design of generative elements in digital environments. For example, in art installations and exhibitions of various types, communicative purpose and potential are realized through the design of affordances for enactment and multiple combinations and iterations (e.g. Reas and Fry 2006). Meaning is generated through the emergent and *communicative* interplay between users' and systems' agencies (Ehn 2006; Morrison et al. 2010).

We now turn to two examples of digitally designed artefacts and environments that illustrate these developments relating to Communication design. The first is a collaborative project, *Ballectro,* exploring how digital elements may be a part of a dance performance work and its mediation as research and extension to other related projects. The second example is from a project developing new ways of mediating cultural heritage carried out as participatory process with school children and a museum. Related theoretical and analytical frames are discussed further in Chapter 3 in sections on relations and networks, and on socio-cultural approaches to communication design.

The Digital in Choreography, Performance and Mediation

The 'performative turn' in post-structuralism is perhaps under-articulated in design research. However, it is increasingly present in electronic arts, where design and performance (as professions and disciplines) are themselves being reconfigured *by their being performed*. Mixed reality works, media, digital tools and computational systems may be seen as actors in performative domains (e.g. Sparacino et al. 2000). Mixed reality refers to a flexible, emergent blend of media types and modes of mediation in which movement or oscillation between pixel and place, bit and site are in play. In this context, technology becomes an actor. This is especially so in electronic arts in which the white cube of the gallery and the distanced gaze of the viewer are transformed into spaces and designs for performativity by participants, with design still embedded in aspects of digital works but not necessarily written on their 'outer skins'. There is, then, a move from representation to performance (Sha and Kuzmanovic 2000), and this extends from installation arts to net-art and gaming (Lindley 2005) and onwards, processurally to the role of time in ludic design and enactment (e.g. Lemke 2005).

Developments in electronic arts stress the multi-sitedness of works, lodged between curatorial and artistic practices and viewers' uptake and touch. Viewers engage in the effecting of the performative as processural as much as in attending to the designed result, where results, too, are modified and reshape their perceptions and expectations, often drawing them into meta views of these activities as making, designing and expressing. The viewer as the one who fulfils the artwork may also be extended to a multiplicity of participants, across networks and relations in their unfoldings. A particular challenge here is to locate not only where design takes place but indeed when it occurs, and the status we give it at that time.

A number of terms have been invented to express these new qualities. Manovich (2003), for example, refers to the 'loop' as part of the realization of 'cultural software', pointing at the recombinatorial qualities that digital storage and retrieval enable. Mignonneau and Sommerer (2003) discuss how a digital poetics – Aristotle's fictive construction: that which is fashioned, shaped, and given identity by being given form – is a blend of programming and user's patternings. The terms 'software art' and 'software aesthetics' (Fishwick 2006) have been developed to capture such a jouncing, or movement, between the designed and the emergent and their attendant texturings as a poetics built on uncertainty and the liminal, and not

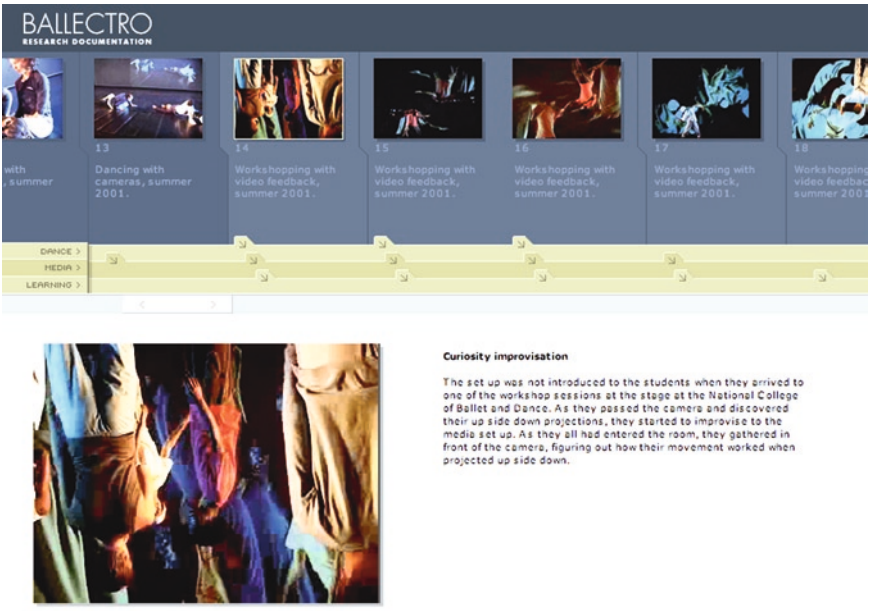

Fig. 2.8 Video and text based documentation in the *BallectroWeb*[1]

[1] The media track has been selected and a video on media with accompanying text is served. The text has links from this choreography and digital scenography workshop session to a final performance. Available: http://imweb.uio.no/ballectro/

on fixity and immovability (Reiser 2003). The term 'generative art' conceptualizes the very nature of the oscillation between a system with some degree of autonomy and our embodied engagements with it (Galanter 2003). Digital designs are seen as being built of networks of complex meaning making that also depend in part on our prior understandings and ontological interaction (Walker 2003). In electronic arts, we may enter into acts of performance that shift the stage, staging and the role of the performer in varying relations of presence (e.g. Murphie 2003). Increasingly these involve embodied interaction (e.g. Dourish 2003; Larssen et al. 2007) in which mixed reality performative spaces and mediated enactments unfold.

These are some of the challenges that face digital designers and artists in their collaborative explorations. We now address this with reference to a previous project called *Ballectro* (Fig. 2.8). This was a collaborative communication design and performance project that drew together designs for choreography, the shaping of digitally mediated scenography and processes of collaborative learning between higher education dance and media students. Methodologically, *Ballectro* worked towards the exploratory production of a dance performance work through workshopping, improvisation, guided pedagogy in choreography and experimentation with elements of digital scenography. The team included a choreographer-educator, herself a dancer and choreographer, a group of final year degree level choreographers, and three media designer-researchers supported by a small technical team. Attention to media elements as part of the wider performativity of the piece allowed us to see choreography and dance as enacted on an extended 'stage'. The mediated projections were moved by hand to follow the dancers' movements, for example. This focus was taken up in a later project, also with student choreographers and this time with media students, called *Extended*. On the basis of this interplay between dance and digital media, a further installation work *Tapet* (meaning wallpaper in Norwegian) was devised. We have analysed this in terms of multimodality and multi-level activity in the interplay between responsive and generative elements where the performativity of the viewer-participant is central (Morrison et al. 2008).

As part of our design and research inquiry in the domain of Communication Design, we developed an additional element to the *Ballectro* project. In the *BallectroWeb*, we developed a multi-level, multimediational website to convey the variety of activities involved in the process-based project. Here the digital design included video documentation, which we then selected and included as a core feature in the multi-level interface. This interface was designed together with a web designer (a media and informatics student), taking the production and performative component in choreography into the mediation of the project as research. We devised a three-track representation (dance, media, learning) with corresponding broadband video. Internal links in this XML and *Flash* based site also allow users to see jumps between workshops and final performances. We have analysed this site as an example of an experimental digital research rhetoric (Skjulstad and Morrison 2005). In this analysis we developed a set of core concepts for framing 'movement in the interface'. The site has become part of our portfolio of research by design, where practice and analysis are intertwined, constituting material for research

conference presentations (e.g. Morrison et al. 2004) that have, themselves, referred to moves from the linguistic and gendered focus on performativity (Butler 1997) to ones of multimodal and multi-activities that involve the digital in design and enactment (Morrison et al. 2010). The focus on kinetic and dynamic aspects of interface and communication design in the *BallectroWeb* has been further investigated in a recent multi-partner project, called *RECORD,* in interface design for dynamic media and social networking. Morrison and Eikenes (2008) have investigated how social semiotics may be drawn upon to devise a set of broad categories for characterizing the relations between moving media and kinetic features of navigation in interfaces; an intersection Eikenes has termed 'navimation'.[2] The longer-term project goal is to connect the performative across the graphic and informational design of kinetic interfaces for laptops and mobile devices to richer inputs from users in building the performative into interaction design: a field that is in need of further humanities research in addition to that from Human Computer Interaction, that often has more functionalist flavour.

Developments and research in electronic art have now built up a considerable body of both theoretical and applied work that applies to digital design in explorations between the technical and the expressive. This body of work offers digital design research additional substance with which to further build transdisciplinary knowledge in which designing for participation may now also include *designing for performativity (*Stuedahl 2004) *and performing design* (Skjulstad et al. 2002). This is taken up in Part 2 of the book in a chapter that explores the design of a social network service and the roles of users' performativity in its iterative design (see Chapter 8).

Engaging Digitally with Cultural Heritage

In the domain of digital cultural heritage communication, numerous digital design projects focus on new and engaging ways to communicate, in particular with young people. On-site, in the museum's exhibits, audiovisual and tangible user interfaces are designed to support visitors' interactions with replicas of objects and exhibition spaces. One example is an interactive chair that supports reflection upon art masterpieces by way of audiovisual communication. The chair is shaped like an egg, big enough for young people to crawl into and providing possibilities for listening and reflecting, together with a voice posing questions related to the exhibit (Gottlieb et al. 2004). Other types of reflection are encouraged by interactive desks supporting collaborative activities related to the exhibit themes (Hall and Bannon 2006). Digital traces of museum visits based on RFID-tags are used in science museums for making dynamically-produced reports on individual museum visits, collecting information about objects visited, and communicating them online (Hsi and Fait 2005).

[2] For further details on RECORD, please see: http://www.recordproject.org/index.php/about/

The value of mobile context devices for guiding in museums (Abowd et al. 1997) has been challenged by the unintended side effects of their rather demanding interfaces, which in fact promote a rather individual, isolating experience that directs the visitor's attention towards the device rather than to the exhibit (Proctor and Tellis 2003; vom Lehn and Heath 2005; vom Lehn et al. 2005; Angliss 2006a, b). PDA based electronic guidebooks that promote interaction between museum visitors through content and audio sharing (Luyten et al. 2006) have paved the way for more flexible and mobile interactions between visitors that are meant to support collective reflection.

Mobile cooperative and educational games (Laurillau and Paternò 2004) introduce new genres of interaction between museums visitors and the exhibit by engaging them in, for example, trading games (Luyten et al. 2006). Lately, mobile telephones represent a step further in the development of visitors' interactions with museum objects, where the mobile telephone can be understood as an exhibition tool (Kahr-Højland 2006) that can support visitors' constructions of learning trails (Walker 2007). Earlier studies have shown that the success of exploring a museum exhibition using digital media is highly dependent on the familiarity of the users with the media (Falk and Dierking 2008). One argument for focusing on mobile phones for engaging a group of young visitors is that earlier projects have shown that visitors with limited technical knowledge tend to concentrate on the content-focused hand-held devices (Falk and Dierking 2008).

There is a growing understanding of the development of social media as major challenge for museum communication. A new museum identity is established by museums using podcasting, weblogging (Russo and Watkins 2006), tagging (Chan 2007; Trant 2006), bookmarking, image sharing, RSS syndication and other web 2.0 resources. The use of these media paves the way for new relations between museums and society, as well as for the positioning of museums in relation to the development of popular culture. Opening up for new ways for public participation in museums presents considerable design challenges in relation to types of engagement, types of referential material and ways to include visitors (Salgado 2008).

Here we describe a design-based research project for digital cultural heritage communication related to the reconstruction of a Viking boat. A design experiment was set up inside a museum that had no technical infrastructure and digital content. A solution to the lack of technology was to set up a mobile media centre at a gallery level that did not interfere with the museum exhibition, but still had a spatial relation to the exhibition. The infrastructure for digital communication by mobile telephone and a museum-visit wiki made on-site support for the teenagers' museum visit possible. The design also enabled us to observe how digital communication of a historical reconstruction project of a Viking boat could happen in a museum setting.

The installation was set up to study digital cultural heritage communication with the target group of young people, 10–15 years of age, that has limited knowledge about Viking boats, but has some knowledge about Viking times from history education at school. A major design ambition was to build a relationship with young

visitors by way of the media they use in their everyday life, such as mobile phones and social online media. The mobile phone represents personal media that are deeply involved in identity construction and the social life of young people (Prøitz 2007). Norwegian teenagers are quick adopters of new technologies, and the diffusion of mobile phones among this target group is rather high. These studies show that young people are competent users of mobile phones; however, the knowledge differs with age. We arranged a design experiment with a school class of 13 year olds, and learnt that the majority of the class was familiar with technologies for uploading files by way of proximity-based technologies such as Bluetooth. A later design experiment taught us that 10 year olds share knowledge about the use of cameras and sound services on mobile phones, but that they understand less about the relations to other media in space.

The design was based on the idea that using the mobile phone for taking pictures and answering a set of questions during the exhibition visit would be motivating. The phone would be a tool for interaction with the information offered in the exhibit. Also, its character of being personal as well as a social media makes the mobile phone an important tool for engaging young people in the exhibition.

Two design concepts in support of the explorations and interpretative work of young exhibition visitors was implemented: using mobile phones for (a) collecting information (see also Walker 2007) and for (b) exploring the artefact's history. Collecting has been conceptualized as an activity that museum visitors perform collaboratively or individually. In the design, this was realized by introducing the youths to alternative narratives about the Viking ships, asking them to find traces of these in the museum exhibition. The young people used their own mobile phones or they used the phones of the project. All mobile phones had integrated camera and video recording features. The task was to document alternative arguments in the museums exhibit, and to publish these on a visitor wiki in the mobile media centre (Fig. 2.9).

Fig. 2.9 Using mobile phones for collecting and sharing cultural heritage interpretations

The media centre is built with an ICEbox (a mobile device for broadband service using the NTM cellular system). This helped solve the problem of lack of Internet connection in the museum. The youths had to upload their video recordings and pictures by way of Bluetooth features, and comment on these on the wiki-page made for their group. The multiple narratives of the visitors were, in this way, given a voice (Fig. 2.10).

Fig. 2.10 Sharing and collaborating at the temporal media centre

One key observation was that taking pictures and videos can be part of the meaning making activities visitors engage in. By taking pictures and video sequences with their mobile phones, and writing text pieces on the wiki, the interpretative work became more media rich and more active during the museum visit.

The experiment illustrates that the engagement of the visitors in creating their own narratives is encouraged by the possibilities of interaction with museum objects in the museum space. Also, the narratives about alternative content offer an opportunity for interaction. The digital design of the exhibition is performative in that the exhibition space is planned in relation to its visitors' meaning making, drawing on a network between architecture, artefacts, texts, visual material, visitors, curators, researchers and designers. Visitor meaning making can only be enhanced by personal media if they enable visitors to personally customize their visits in ways that build on and make use of their prior experiences, connect to their social group and support their motivations for visiting, and their interests before, during and after the experience

The cultural heritage and the mediated performance examples given above illustrate how the possibilities for interactivity created by digital designs challenge earlier humanist theoretical foundations and open up for new ways of conceptualizing and understanding human communication and cultural processes (e.g. Bolter 2003). They also exemplify a 'constructive approach' from a humanist perspective: they are oriented toward making and experimenting with the digital elements of communication – challenging traditional humanist research values and practices, but also drawing them into processes of digital designing.

The Practices of Digital Design Research

The diversity of digital design research projects has prepared the ground for reflections on design practice and the practices of digital design research. Researchers perform ethnographic studies of design, studying the practices as they unfold, or are

initiating and/or participating in design while studying it. In the first case, designers and researchers are different people, and very often researchers observe design practitioners engaged in a result-driven project for a client. In the second case, researchers participate in carrying out design and reflect upon their own practice. In this case, the design practice is also a research practice, constituting a different frame for the design process: less emphasis on producing a design within sometimes narrow budgetary and time constraints and more emphasis on experimenting with innovative materials, forms, and methods where failure is also a (research) result. Some design practitioners deeply engage in experimentations but do so with the aim of producing an innovative design result for a client, while researchers may sometimes go on experimenting, losing the grasp on their aim to create a novel, exciting solution. Design experiments within research projects are therefore different from design experiments in result-driven design projects – but still may provide insights into design. Both types of research are important sources for knowledge about design practice. Studying design practitioners at work helps us understand the everyday skilful activities that go into design work. Doing design experiments focuses on uncertainties, and questions these work practices in specific ways. In the last two cases design is a method for research driven by theoretical positions, what some call design-based research.

In the following, we discuss aspects of design that we see as crucial to understanding the practice: design as a collaborative activity that sometimes involves a large network of actors (client, investor, specialists of all sorts, and more); the multidisciplinarity of design work, which influences the ways designers express, represent, and communicate an evolving design concept; the role of artefacts and materials; the diversity of material practices which shape the design object, their historical-cultural roots and specificity; and the multiplicity of the design object itself, its changing representations in different media, and how it gets translated/transformed in the process of design.

Design Practice as an Object of Research

At the centre of design is the making of things that will enter into somebody's practices – design is itself a contextual and situated activity. We see design as a situated doing and undergoing, experiencing and expressing of people as they engage in practical action, often together with others. We look at design work as open-ended, exploratory, complex, continuously produced, and intensely collaborative and interactive. Design practice is the activities that designers engage in when doing design.

The design process is a difficult object of research. It does not have a clear starting or ending point (Krystad 1997; Bratteteig 2004a), although we may study design between the formal start and end. Design ideas, inspirational materials, professional and social connections are constantly being attended to, also before any contract has been signed or kick-off meeting has been held. The end of a design

process may be when the design description (specification) is handed over to someone implementing the design (Bødker et al. 2004), when the design object becomes a 'thing', or we may include use, maintenance and redesign until the life cycle of the artefact ends (Bjerknes et al. 1991; Bratteteig 2004a). Much of the design process happens in people's heads or in conversations, maybe leaving only inscrutable scribbles on white boards and napkins (Newman 1998; Henderson 1999).

There is a long history in design research of investigating design practice as a basis for understanding design. Most influential has been the work of Schön (1983, 1987), who studied design practices across a range of design disciplines (architecture, engineering etc.) and discussed design as a reflective process, illustrating how design practice differs from the formal models of design popular at that time. He maintains that design is a process of 'naming and framing' the problem, and that the problem setting is as important to design as problem solving. Bucciarelli (1994) carried out detailed ethnographic studies of engineering projects and describes through a series of stories from design work how engineers work with different 'object world' materials and representations. Lawson (1997, 2007) studied architects' thinking and Cross (Cross 1984, 1994, 2007; Cross et al. 1996) investigated product design and use of design methods a basis for discussing 'designerly ways of knowing'.

Studying designers at work has been an important part of information systems (IS) and PD research from their beginnings. Mathiassen (1981) applied Schön's concept of reflective practice for building a theory of information systems design (cf. Andersen et al. 1990). Stolterman (1991) developed a model of design in information systems development based on an empirical study of design work. One of his key observations refers to how systems designers developed 'an operative image' – a vision – very early in the design process. He argues that the 'sketching' activities leading up to the 'specification' should be seen as parallel activities at different levels of abstraction (or concretization, see Mörtberg 2001; Bratteteig 2004a). Winograd (1996) includes stories by software designers and design researchers about (their) design practices and argues for 'bringing design to software'. He looks at design as a conscious, human-oriented, materially-focused, creative, communicative social and political process. The political is put forward in PD, where the focus is to design better tools for users and their work practices by widening the number of people who participate in making design ideas and design evaluations (see Nygaard and Bergo 1975; Bjerknes and Bratteteig 1988b, 1995; Ehn 1989; Greenbaum and Kyng 1991; Bratteteig and Stolterman 1997).

Within CSCW there have been very detailed studies of design work. Among the 'classical' studies are the ethnographies of software developers at work by Button and Sharrock (1994). Grinter (1996, 1997, 1998, 2003) has studied software development teams in a variety of settings. She has, for example, looked into the adoption of a configuration management tool by software developers, into how developers engage in recomposition so that the organization can assemble software systems from parts, or how system architects garner support and commitment from distant departments, always with a focus on the collaborative aspects of design work. Potts and Catledge (1996) describe a detailed field study of a large industrial

software project where they observed the development team's conceptual design activities for 3 months, with follow-up observations and discussions. They emphasize the organization of the project, and how patterns of collaboration affected the team's convergence on a common vision. Some research projects offer detailed accounts of parts of the design process, like Bowers and Pycock (1994) who document some of the details in the design of a computer interface, analysing dialogues between a programmer and a user about how to get the details right. Tellioglu and Wagner (2001) discuss the notions of place and boundaries to identify sources of heterogeneity, and to understand how these are oriented to within the practicalities of design work. Mörtberg (1997) analyses the gendered work practices and discusses the negotiations between professional and gendered practices that take place in design work. Robertson (1997) studied design teams working over a distance, analysing how their embodied work knowledges made sense over distance. These analyses of digital design practice deeply challenge notions of design as embedded in formal 'scientific' methods and models of digital design, like those presented in software engineering (see Bratteteig 2008).

The emergence of new digital artefacts, such as 'social software', poses additional challenges to digital design research. These digital artefacts leave more space for users to (continue to) design social environments for communication with other people. The design of the digital artefact enables communication – if the functions and meanings are communicated so that it is clear how the artefact can be enrolled into a practice (Bratteteig 2002), which thereby changes its meaning and function. The roles of designers and users become blurred and encourage a discussion about when design stops and use begins (cf. e.g. Brand 1995). Attention to the 'performative' focuses on the negotiations between actors, and invites us to study purpose, intentions and strategies – those that are visible and articulated, as well as those that are invisible and silent (Star and Strauss 1999; Berg et al. 2005; Stuedahl 2004; Mörtberg and Stuedahl 2005). The narratives created may be displaced by other versions and accounts, and multiple performances may draw together alliances between participants and technologies. Design by users after design contributes to changes in the designer-user relations and roles challenging established work organizations and knowledges. However, producing 'content' in a digital system often does not require skills or knowledges in digital design – and does not necessarily make the user into a designer. Furthermore, design after design most often happens within already designed limits – whether or not the user is aware of them. Designing for 'design after design' aims to lower those limits.

Collaboration in Design

'Design is both individual and social, and involves people with different skills and knowledges … in what can be seen as multidisciplinary, cooperative, constructive negotiation.' (Bratteteig 2004a: 127). Chapter 1 gives a brief overview of the broad range of (inter)disciplinary sources we draw on in this book (Fig. 1.2), and Chapter 3

goes into some of these in more detail: CSCW, socio-technical and socio-cultural approaches pointing to humanistic research, and feminist critical technoscience. Typical of design work are the different types of collaboration it involves – collaboration within the design team and with external specialists, collaboration with users and/or clients. Schmidt and Wagner (2004) describe the work of designers as a 'mixture of concurrent, sequential, and reciprocal action' (p. 350), partly co-located and partly spatially distributed, and communicative. Collaboration, coordination and organization of work form an important part of design and design knowledge in systems design (Andersen et al. 1990).

Practices of collaborating and sharing, if with words or through artefacts, if face-to-face or mediated by technology, vary enormously, depending on the stakeholders involved, on their having a history of collaborating with each other, the constraints a project has to face, and so forth. Design as practised by design practitioners is very often a task given by a client, who to a varying degree specifies the task beforehand – limiting the problem space and/or the resources (people, time, materials, see Andersen et al. 1990; Borum and Enderud 1981; Bjerknes et al. 1991). The client may already have defined a problem to be solved, which may make it very difficult to suggest alternative problem definitions (which is what the first PD projects were all about; see Nygaard 1996).

Large design projects need to engage a variety of external actors. They have to enlist many professional competencies, ranging from basic architecture and infrastructures to interface design. An architectural project typically includes technical consultants for construction, electricity and heating to specialists for façade construction and materials. Mobilizing their support and integrating their perspectives requires careful preparation and ongoing communication. When it comes to digital design small projects may also have to integrate multiple perspectives and skills. Wagner et al. (2002) describe how, in designing the 3D visual archive of 'Wunderkammer', designers combined an architectural approach with the language of film, comics, painting, and stage design and explored the suitability of these visual languages for a digital medium. In multimedia production, strategic partnerships and networking activities are very important – cooperation with specialists in, for example, video processing, journalism, film making, graphic design, comics, and music; contracting out, for instance maintenance or programming activities; mergers, joint ventures, strategic partnerships; cooperation on the Internet by means of newsgroups, mailing lists or free groupware.

In addition to including different competencies, large software design projects may spread out globally, implying a variety of relations between people and teams in the larger project. Outsourcing – the distribution of work tasks – requires unambiguous written communication, which turns out to be near to impossible (Sahay et al. 2003; Imsland et al. 2003). A study of an internationally-distributed software team demonstrated that many of the collaboration difficulties and conflicts between distributed team members had their origin in language problems (Beyene et al. 2009) and cultural differences (Hinds and McGrath 2006; Hinds and Bailey 2003).

Nardi and Whittaker (2002), in studying cross-organizational collaborations in multimedia production, such as between a designer team and consultants, vendors,

etc., have introduced the notion of intensional networks, arguing that 'collective subjects are increasingly put together through the assemblage of people found through personal networks rather than being constituted as teams created through organizational planning and structuring' (p. 205). Designer teams need the skill to build, maintain, and extend such networks of people that have the shared experience of joint work and knowledge about each other's work skills, styles of communicating, etc.

Many researchers have adopted the notion of community of practice (Lave and Wenger 1991) to underscore the sometimes long experience of collaboration needed to be able to skilfully perform tasks and produce high quality outcomes. We talk of a community of practice when we observe a shared repertoire of ideas, commitments, and memories, as well as common resources (tools, documents, routines, vocabulary, symbols) that in some way carry the accumulated knowledge of the community. This applies to design teams and can also apply to some forms of user participation in design. Involving users in design ranges from inviting them to evaluate design suggestions (e.g. Nielsen 1994), to participate in designing the user interface (Bowers and Pycock 1994), or even to participate as co-designers, having a voice in setting the design problem as well as developing a solution (Bjerknes and Bratteteig 1987; Kyng 1991). In the last case, the users become members of the community of practice that constitutes the design team – opening up for additional possibilities for design by including a different set of experiences and competencies from which to build design ideas. To have the design team base their design on a broader range of perspectives ('placements' cf. Buchanan 1995) requires a process of mutual learning and the building of trust and respect for all competencies involved – including both design and use contexts (Bjerknes and Bratteteig 1988a; Bratteteig 1997, 2004a).

Diversity of Artefacts and Material Practices

Given the intense collaborative character of design work, we can say that at its heart, therefore, is the need to share materials and to mobilize support. Designers' artefacts have a crucial role in this process. They are created and used for expressing, developing, detailing, communicating, and presenting an evolving design concept. Designers work with materials, translating and transforming them until they converge to a 'thing' (De Michelis 2009). The explorations of the materials that are part of design often have their origin in a larger context, even if they may be carried out in a lab – outside of that context. However, they cannot be fully understood unless brought back to that same context for use in a practice.

An important characteristic of design work is that it is open-ended. With Lave we consider designers' situated doing and knowing as 'inventive' in the sense of that they are 'open-ended processes of improvisation with the social, material, and experiential resources at hand' (Lave 1993: 13). The need to maintain openness in a design project has implications for how designers collaborate. Openness means that decisions about possible design trajectories should not be made too quickly,

and requires that the different actors present their work in a form that is open to the possibility of change. Here, designers' artefacts play a large role.

Many studies point to the richness and diversity of design representations and working materials, which include plans, sketches, physical models, samples, flow diagrams, story boards, probes and prototypes, game boards and props, as well as the full range of 'normal' documents; and the diversity of the activities that constitute them, which range from the aesthetic, creative and imaginative, to the technical and scientific. Designers' sketches or (3D) visualizations are often conceptual and metaphorical; they are open to extensions, modifications, and novel interpretations, inviting others into a dialogue (Henderson 1995; Bjerknes and Bratteteig 1988b). A design representation may be created primarily for expressing qualities of space, interaction, light, atmosphere, and materials; providing a vision rather than a detailed specification. For this, designers may mobilize a diversity of resources – artwork, concepts and metaphors from other fields (e.g. from biology, mathematics, drama), analogies, video clips, project examples, samples of materials, and technologies. Designers of physical things collect materials that they display, constituting an inspirational design space while maintaining an account of the design team's history.

In a study of engineering work, Henderson looked at the role of visualizations as 'network-organising-devices', acting as 'individual and interactive thinking tools, organisers of interdisciplinary communication, either being discussed and worked on cooperatively, or being handed off, enlisting additional work and knowledge' (Henderson 1995). Schmidt and Wagner (2004) make a distinction between artefacts that are primarily designed to help manage the complexity of coordinating and integrating cooperative activities (coordinative artefacts) and representational artefacts that make the 'not-yet-existing and in-the-process-of-becoming field of work immediately visible, at-hand, tangible' (p. 363). The role of designers' visualizations in the absence of the object of communication has been observed by others (cf. Newman 1998). Henderson (1995) uses the notion of 'conscription devices', which she borrows from Latour (1986), who pointed to the advantage of visual and graphical material in its ability to create 'persuasion' and to invite others into a dialogue. The design of the 3D visual archive 'Wunderkammer' illustrates the diversity of artefacts: sketches, visual examples, and the prototypes themselves, and their crucial role in creating a persuasive way of including different specialists (architect, graphic designer, 3D designer, and computer graphics specialist), into the process of design. Wagner and Lainer (2003) argued:

> The user interface of a prototype is an image, which is open to interpretations and discoveries. It is resonant with multiple voices, inviting participants to activate their imagination. It is incomplete and preliminary, yet very concrete. It is concrete in the sense of being visible and tangible, offering users as well as designers the possibility of manipulating, exploring, and evaluating what has been achieved. It clearly is something preliminary and unfinished – a *placeholder* of something to be – and as such gives space to ideas of what to change, how to develop further, including alternative or novel ideas, of how to approach the design (Wagner and Lainer 2003: 18).

Observing designers at work, we can see how having the diversity of design representations available, reading and re-reading them from different points of view,

eventually going back to a moment when a particular issue emerged, is crucial to design. Much of individual and cooperative design work is done through creating assemblies of materials for representing and envisioning a problem, task or solution. These assemblies represent design representations 'in context'; one of their central features is their narrativity. Assembling and reading materials such as sketches, drawings, samples of materials, diagrams, storyboards, and so forth, is a fundamentally collaborative process, which helps the designer team to:

> Create a common understanding of a design idea or task; Talk about a design in a rich, metaphorical way, supported by images to be pointed at and referred to; Imagine qualities of space and appearance, which could not easily be communicated in words; Act as reminders of design principles, approach, method, open questions, etc.; Preserve the memory of a design solution and the arguing behind it (Wagner 2000: 387).

The work of detailing a design solution is often referred to as sketching (Henderson 1999; Cross 1995; Arnheim 1995; Buxton 2006) but design practices show that many other different ways of concretizing design ideas are used.

Linde (2007) describes design work 'as an act of metamorphing, to create the metamorphoses of the objects of design and to reflect on the effects of the changes is at the core of design work'. Representations are translations of ideas into new forms, with new 'languages'. Translations are always also interpretations, adding and subtracting meaning and emphasizing particular aspects and silencing others (see Mörtberg 2001; Bowker and Star 1999). Digital design researchers have observed that some representational methods and tools impose very limited languages on the translation, thus constraining both, what the problem and the solution can be (Bjerknes and Bratteteig 1988a). In digital design, these translations can involve many types and layers of translation that make use of very different materials that in the end become part of the design result, seen as a whole.

The final representation – the 'thing' to be handed over – is either the finished design or the specification supposed to instruct someone else to build the design and make the vision real. The specification is mainly a communication device that may function well if the designer knows enough about the production and is able to communicate unambiguously to the builder, which is often not the case and the actual builder has to develop his/her own interpretation and solution. Even if the designers take a final decision, the 'thing' is subject to change through the appropriation of the users and integration with culture and everyday life – but within limits set by the designers' decisions.

Closing Comments

In this chapter we have moved from presenting and analysing a set of digital design stories – our own – to more general reflections on digital design, with a focus on designers' material practices and on the artefacts they create, share, translate and transform. We have looked at design practice as researchers, from a perspective that

is nourished by a diversity of traditions and experiences, to address some of the core questions of this book: what are the ways in which we come to know what we know about design and design practice? What relations are there between making and reflecting? What place does knowledge in, through and about practice have for digital design research?

There is knowledge that lives in the design process and is embedded in designed artefacts. There is knowledge we generate as researchers-observers, and knowledge that stems from also being engaged in making digital designs – which sometimes involves making them happen as an occasion for studying them. Our examples cover this range of design and research practices. The story of the *Sisom* project has been written from the perspective of a PD researcher and practitioner, who critically examines the evolving design, looking into how many of the children's ideas and activities have influenced the design. The focus is on PD practice. The story of the tangible user interface in support of collaborative urban planning is the outcome of a close cooperation between design practitioners and researchers and reflects both perspectives. At the core are ethnographic observations of users working with the tool, with a view onto re-design. The *Ballectro* project is also evidence of a multimodal bridging of design and design research, addressing the issue of how to combine and integrate a live dance performance with its digital representations. The cultural heritage example is the first phase of a project on experience design for young people engaging in conventional, non-digital environments – such as in museums where cultural heritage objects play the main role. The digital design here focuses on supporting experiences of the authentic.

We have identified different practices that are genuine to digital design: participation with users in the design, cross-disciplinary cooperations, such as analysis of use and re-design, engaging users to experiment with and explore digital designs, translations between media and modalities, and so forth. We have analysed different design representations and their role in design and use situations.

In the second part of this chapter, we expressed these observations on a more conceptual level, exposing a multi-disciplinary analysis that has proven useful for thinking and doing digital design. The first section discussed the work practices of digital design with the aim of pointing to different bodies of research that analyse these practices in different ways. The second section addressed the collaborative nature of design practices and the many different types of actors and roles involved in design. They all influence the design process as well as the design result. At last, we covered the materiality of design: the object of work as it develops through cycles of intermediate forms and conceptual translations, finally becoming an artefact that can act as a design result. Design practices are these translations and transformations: to understand design we need to see the skills and knowledges at work. Our research adds more disciplinary and interdisciplinary perspectives, more layers and relations in the practices of digital design, enabling a richer understanding of how they evolve.

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