Toward Place-Centric Computing: Making Place With Technology Together

Henrik Korsgaard

PhD Dissertation

Department of Computer Science
Aarhus University
Denmark

Toward Place-Centric Computing: Making Place With Technology Together

A Dissertation
Presented to the Faculty of Science and Technology
of Aarhus University
in Partial Fulfillment of the Requirements
for the PhD Degree

by
Henrik Korsgaard
December 31, 2016

This version has been edited since the defence (June 2017). Edits include removing duplicate references and minor formatting issues.

Abstract

The narrative is well-known, computers have left their position at the desktop at the workplace and have become ubiquitous to our everyday lives and the places we inhabit. Public displays catch our attention as we pass by, network infrastructure transform how we see and use places, and take their place in the activities we engage in. We use our personal devices to get into place, to navigate and participate in situated activities.

The present work focus on the places we inhabit as the common focal point for human activities. It employs the notion of *place-centric computing* as a lens through which we explore how people use and develop technologies together as part of place-based activities, and subsequently propose an alternative foundation for place-centric computing in the form of an infrastructure perspective.

The focus of the dissertation require a combined methodological approach. One goal is empirical and seek to *understand* how people already engage in complex patterns of improvisation and appropriation of heterogeneous, ubiquitous technologies as part of the place-specific activities. Another goal is technological and seek to make this common information space a more integrated part of the place itself, in how people access and use it, the technologies that can be integrated in - and evolved with - a place and its practices. Ultimately, I want to propose a technological foundation that support the human need of getting into place *with* technologies.

The combined methodological focus concerns *computational alternatives*, where the empirical insights are carried into the experimental work through the conceptual focus. This perspective introduces a socio-technical focus in the research where neither practices or technologies can be explored independent from each other. This is the methodological contribution of the research.

This dissertation makes contributions of two kinds. It conceptualises the community technologies from an ecological perspective with the notion of *community artifact ecology* and describe the community efforts in its development. It proposes a technological foundation focused on integrative technologies and infrastructure.

Resumé

Det er en velkendt fortælling. Computeren har for længst forladt sin eksklusive placering på skrivebordet og arbejdspladsen, den er blevet allestedsnærværende i vores hverdag. Skærme fanger vores opmærksomhed i det offentlige rum, netværksinfrastruktur former hvordan vi oplever og bruger vores omgivelser og er spiller en aktiv rolle i de aktiviteter vi deltager i. Vi bruger vores personlige enheder til at finde os tilrette og deltage i sted-specifikke aktiviteter.

Denne afhandling fokuserer på de steder vi indtager og opholder os som et fælles udgangspunkt for menneskelige aktivitet. Den fremsætter *sted-specifik informations teknologi* som et perspektiv i udforskning af hvordan mennesker bruger og udvikler teknologi i fællesskab, som en del af deres sted-specifikke aktiviteter. Efterfølgende forslås der et alternativt grundlag for sted-specifik informations teknologi med fokus på lokal infrastruktur. Dette indikerer en kombineret metodisk tilgang. Første formål er empirisk og søger at *forstå* hvordan mennesker allerede bruger og udvikler en række forskelligartede teknologier gennem improvisation og tilpasning i fælles sted-specifikke aktiviteter. Andet formål er af teknologisk karaktér og undersøger hvordan udvalgte teknologier kan forankres og integreres i det enkelte sted. Dermed gøres de lettere tilgængelige for de der deltager i de situerede aktiviteter. Ambitionen er at disse teknologier skal kunne udvikle sig med stedet og de situerede praksisser, for dermed at gøre det nemmere at understøtte vores behov for at indrette og tilpasse os til stedets muligheder, *med* egne og stedets teknologier.

Den metodiske position har til formål at udforske *teknologiske alternativer* hvor empirisk funderet viden konceptualiseres med henblik på at give retning til eksperimentel systemudvikling. Dette metodiske perspektiv introducerer et socio-teknologisk fokus hvor hverken teknologi eller praksis kan udforskes uafhængigt af hinanden. Dette er afhandlingens metodiske bidrag.

Denne afhandling bidrager på to områder. Den konceptualiserer de teknologier folk anvender i fællesskab fra et økologisk perspektiv med begrebet *fællesskabets artefakt økologi* og beskriver fællesskabets udfordringer med at udvikle disse teknologier. Det fremsætter et teknologisk fundament med fokus på infrastrukturer, der kan integrere eksisterende teknologier.

Acknowledgments

This dissertation would not have been possible without the help and support from good colleagues, friends and family. I am grateful for your support, encouragement and generosity throughout the years.

First and foremost, I would like to thank my supervisors. Thank you Susanne Bødker for giving me the opportunity, continuous support and advice throughout the last three years. Thank you Clemens Nylandsted Klokmose for sharing your visions and insightful comments, and for guiding me into the strange world of software development.

I would like to thank the co-authors of the included publications. I have attempted to be consistent in using “we” when referring to the work we have developed together. Thank you Susanne Bødker, Clemens Nylandsted Klokmose, Joanna Saad-Sulonen, Peter Lyle, Jens Emil Grønbæk, Henriksen Birk, Marianne Graves Petersen and Peter Gall Krogh.

A special thanks to everyone at the Department of Information Science at University of Colorado, Boulder, for making my stay abroad unforgettable. In particular, Leysia Palen and Ken Anderson for making me and my family feel welcome in Boulder.

The list of people who have helped realise this work is long – the list of people who have made it a pleasure even longer. I would like to thank all the awesome people in PIT and CAVI. My great colleagues at the Department of Computer Science and the students who come by to cheer me up – you know who you are.

Lastly, I owe everything to my wonderful family. Dearest Marianne, thank you for the love, confidence and encouragement, I could not have done this without you. Dearest Eva Sofie, thank you for making me laugh and smile when it was needed the most. Thank you!

Henrik Korsgaard
Aarhus, Denmark, New Year's Eve, 2016

Preface

This dissertation is divided into two parts: Part I is a summary of my work throughout the last three years. Part II is a collection of six publications, three that have already been published, one accepted and two drafts scheduled for submission in early 2017.

The summary is further divided into seven chapters. In chapter 1, I introduce the theme with a short introduction to *place* and motivates the research. I present the research objectives and the primary contributions. In chapter 2, I introduce the research methodology and process, and present *computational alternatives* as a methodological contribution. In chapter 3, I present the conceptual and theoretical foundation for my work. I outline previous work on place within our field and discuss the implications of adopting a more place-centric perspective. Chapter 4 present the concept of *community artifact ecology* as a central contribution from the empirical work. This chapter also serve to illustrate the kind of places and activities the dissertation focus on. Chapter 5 is a presentation of four central design experiments informing the conceptual and technological work in the dissertation. In chapter 6, I present and discuss the contributions from the design experiments. Chapter 7 concludes the summary and discuss future work.

Included publications

The selected papers that form the dissertation are listed below. I have published a number of publications in various formats that, while still relevant to my research, have not been included in the dissertation. These are listed in appendix **??**.

[Paper I] Henrik Korsgaard, Clemens Nylandsted Klokmose and Susanne Bødker. *Computational Alternatives in Participatory Design: Putting the T Back in Socio-Technical Research*, In Proceedings of the 14th Participatory Design Conference: Full papers-Volume 1 (pp. 71-79). ACM.

[Paper II] Susanne Bødker, Henrik Korsgaard and Joanna Saad-Sulonen. *'A Farmer, a Place and at least 20 Members': The Development of Artifact Ecologies in Volunteer-based Communities*, In Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing, 2016.

[Paper III] Susanne Bødker, Henrik Korsgaard, Peter Lyle and Joanna Saad-Sulonen. *Happenstance, Strategies and Tactics: Intrinsic Design in a Volunteer-based Community*, n Proceedings of the 9th Nordic Conference on Human-Computer Interaction. ACM, 2016.

[Paper IV] Henrik Korsgaard and Clemens Nylandsted Klokmose. *InPlenary: Designing Systems for Co-located Active Learning in University Lectures*, Draft in preparation for submission to the 2017 conference on Designing interactive systems.

[Paper V] Jens Emil Grønbæk, Henrik Korsgaard, Morten Birk, Marianne Graves Petersen and Peter Gall Krogh. *Proxemic Transitions: Designing Shape-Changing Furniture for Informal Meetings*, Accepted for the 2017 CHI Conference on Human Factors in Computing Systems.

[Paper VI] Henrik Korsgaard and Clemens Nylandsted Klokmose. *local.here: Ubiquitous Computing from a Place-centric Perspective*, Draft in preparation for submission to the 2017 International Joint Conference on Pervasive and Ubiquitous Computing.

Contents

Part I

Summary

Chapter 1

Introduction

Interactive technologies have become ubiquitous and they affect how we perceive and use places. Public displays grab our attention as we pass by [73, 181], dynamic media architecture even more [78], and network infrastructure transform how we see and use places, and the activities we engage in [74, 310]. We observe and use the environment and the interactions of others as cues to our own behaviour and activities [94, 162], in particular when we encounter new interactive technologies [101]. Interactive artifacts join the existing ecology of people, practices and technologies of a particular local environment [268], either momentarily as people bring their personal devices along with them, or more permanently when interactive technologies are installed and fixed into place. They depend upon the complex mesh of local infrastructure, become entangle in both wires and local practices [145, 253], and how the place is perceived and the activities the place invite and support. Consider for instance how displays and media facades have transformed Times Square in New York, and become synonymous with the location itself and perhaps even broader cultural images of contemporary urban life [371]. Or how the proliferation of laptop computers and network technology have transformed a café from a place of public and social life, to a place where people also go to work out of the office [310]. These examples illustrate how places evolve with new technologies and the importance of supporting new ways of appropriating places with technology. The examples also suggest that we need to expand our understanding of the places wherein human computer interaction happen. In particular as computer mediated activities move outside well-established settings and practices into diverse context that may be familiar and meaningful to us as places, but unfamiliar from a technological perspective. The name of the local WiFi network and various dynamic displays are indicators of the hidden technological systems they rely on. In the examples above the place is perhaps the only thing the people occupying the space have in common. The central question is what it means to have a place in common, being collocated and the role technology play and could play in supporting local engagement, participation and collaboration?

1.1 Introductory definition of place

This dissertation explores *place* as a first class object for human-computer interaction. Therefor, an introductory definition and analysis of place is required, before returning to a technology perspective. I based my working definition of place on Gieryn's triadic view of place as geography, environment and culture [140][1]. Place has plenitude and its features cannot be ranked as more or less significant, nor can one be reduced to an expression of another. If one feature changes, the place changes, sometimes subtly evolving over decades, sometimes abruptly through decisive events. Consequently, a place is not a space, backdrop or context for something else, it cannot be describe by what is observed alone, or in its geometry, economics, demography etc. Virtual environments cannot be considered places. They may be constructed and described using the same terminology and draw upon spatial and placial metaphors [e.g. 148, 168, 175, 281], but (spaceless [168]) places they are not. Places are habitats, they are features of the environment appropriated to serve human needs and activities [138], and these habitats and their physical features have developed with our culture [12, 162]. Places are particular and inescapable; we still walk down the street everyday regardless of how we describe our world [75, p.249]. And humans are creatures of habit, we move along the same paths between very few locations [143].

Places have the potential to bring people together through co-presence and collocated activities, foster social interaction, engagement and enduring community relations, as well as spawning and becoming the focal point for collective action, as many historical events show [137, 140]. The fall of the Berlin wall in 1989, the attack on World Trade Center in 2001 and and uprising in the Tahrir Square, Egypt 2011 are well-known examples. Most of our social relations start with co-presence [68] and a majority of human activities depend and thrive on collocation [275, 281]. The quality and nature of social interactions and situated activities are closely related to the spatial organisation and the physical environment. Engagement and estrangement can be built in. Structures that hinder mutual visibility make social interaction less likely and less frequent; spaces designed with social and personal distance in mind and features for resting and lingering result in a higher frequency and longer duration of social interactions [137]. The environment does not create the community, rather it increases the probability [337]. Co-presence is a prerequisite for social interaction, and frequent social interactions in and around familiar places are a prerequisite for community activities and participation [140, 242].

A place supports a broad range of human activities, mediate experiences and evolve with them. Buildings and environments become places through use and continuous adaptation and focus appropriation by the inhabitants to suit their needs and prefer-

[1] When I refer to any individual features throughout this summary, I refer to place, unless otherwise noted.

ences. Brand state that *"[a]ge plus adaptivity is what makes a building come to be loved. The building learns from its occupants, and they learn from it"* [69, p.23]. Similarly, Gehl [137] note that *good* urban environments are those that allow people to adapt and appropriate the public space for a range of social and volunteer activities. Social life depend on the flexibility of spaces. Some adaptions are permanent changes to the environment, whereas others are momentarily appropriations of elements to fit situational needs. Activities and everyday life invertible leave traces and residue, situational appropriations become permanent through habits. Several factors influence how and what can be adapted and appropriated where, and it varies across cultures. Hall [162] talks about fixed-feature, semi-fixed and informal spaces to illustrate cultural differences. What is appropriate to appropriate is not determined by material flexibility and mobility alone, it depends on the place's social and cultural meaning.

Places are enduring and stable when compared to the activities of everyday life. Geography and terrain do not change relative to human perception. The lifespan of buildings and their exterior appearance varies between 20 and 300 years [69]. These temporal scales reflect the scales at work when examining how activities amount to practices, social life and culture [227]. These subtle changes are not registered in our everyday life, *"[. . .] they do not make a difference that makes a difference to us"* (Bateson 1972, cited in [227]). Changes become apparent when we reflect upon or return to a place that has changed significantly since our last visit. Places evolve slowly and accumulates artifacts and technologies, and these artifacts contribute to the place-specific activities and how we reflect on and identify places [69, 253]. Places persist internal structures and artifacts. Most of our everyday objects belong somewhere relative to an activity and a place, e.g. a kitchen or library. Certainly, artifacts move over the course of an activity, but they rarely leave the place where they belong[2]. Things do not change position overnight, practices rely on patterns and permanence of artifacts, and share artifacts are structure and communicate awareness through explicit and implicit spatial organisation [298].

A place acts as a strong filter and locus for people and activities. It filters noise, information, people, activities and behaviour. Different people develop similar behaviour in the same places and different behaviours in different places (Baker 1968, cited in [281]). Locality and proximity is a great privacy filter, walls and doors provide shelter and security, and social cues and social etiquette work as filters of inappropriate behaviour [141, 221]. The place simultaneously filter away what is irrelevant and focus our attention on what is relevant. Places have canonical uses and affordances, they support specific activities better than others [12]. This is most evident in highly specialised functional spaces, lecturing halls, operating rooms, trade workshops, control rooms etc. These spaces are manifestations and crystallisation's of human practices. They bind

[2] The number of personal items we bring with us are relative few. E.g. most of our personal belongings stay at home and work-related artifacts are to be find at our workplace.

and surround activities, impose roles, e.g. surgeon, nurse, and patient, and the physical features and artifacts within is governed by rules and regulation.

Technological tensions

When we return the discussion and analysis to interactive artifacts and ubiquitous computing environments, it is clear that many of the traits of places are absent in how we conceive and architect interactive technologies. A majority of the interactive technologies we use on a daily basis are designed to help overcoming spatial and temporal limitations. These technologies are, according to Mitchell [259], *anti-spatial* in nature. The complex networks negate geography and allow people to find things and people without knowing where they are [259, p.8]. They link people and information at indeterminate locations. Personal and networked computing have transformed our relations from place-based (e.g. door to door and land-line telephony), to personal connections. Contemporary technologies are placeless in the kind of uses they are designed for [355], in their dependency on and connection to global networks [75], through cultural uniformity and homogeneous designs [36](see also [296]), and in popular narratives of *anytime anywhere* computing [285]. The tension between global and local is a tension between the spatial and placial characteristics of technologies. And currently, space and global flow of information dominates over place and local needs with networked and personal computing [75, 86].

When we examine technology and their design, it is clear that these are designed with a strong focus on individual devices and applications as products [see 193], and focus less on how these systems will be embedded and used in particular places and information ecologies [266]. The failure to acknowledge that technologies are introduced gradually one at a time and accumulate in and around place-specific activities is the root of the challenge of legacy and heterogeneity in ubiquitous computing. The purpose built technologies of the elaborate research setups are technologically and ecologically naive [36, 114]. Consumer technologies are designed as one-size fits all and only offer limited interoperability within walled commercial ecosystems and across recent models and versions.

Many of our everyday devices and applications are constructed elsewhere, completely detached from local practices, situated knowledge and evolving needs [193, 331]. They increasingly rely on global infrastructures that further displaces the locality of use from where data is stored, processed, and create value [see 349]. The idea of the 'cloud' neatly abstracts away the fact that it is just somebody else's computer [104, p.30]. Regardless whether data and information reside in an obscure network of data-centres or in individual devices, it is still difficult to share information artifacts outside the personal device and service ecology, yet alone appropriate other interfaces in our environment as impromptu common displays. Software with strong support for collaboration is the exception rather than the norm [203]. Hardware and software design rely on a closed model where the inner workings are black-boxed and shielded from the user, hard to inspect and impossible to modify. Appropriation is a matter of combining and configuring a subset of predefined and closed applications into a working personal ecology [55, 191] and collaboration require negotiating and deciding upon a constellation of shared applications [307]. At large, getting into place with and working across multiple technologies require effort, improvisation and configuration to make ubiquitous computing work [74, 110, 195, 277]. Contemporary technologies do not evolve adequately with the places and communities wherein they are embedded in. They remain largely as designed, with the occasional software updates. Rather, people and communities adapt around these in everyday activities, they *do* messy ubiquitous computing to overcome the limitations of technology [110, 277].

The inherent tension between local needs and global technology designs, and the lack of adaptivity, local control and support for appropriation, is at the core of the recent ecological turn in human-computer interaction research (HCI[3]) [e.g. 94, 149, 193, 253, 256, 268]. The concept of *grounding* technology designs in local places, their physical constituents and cultural meaning, and the needs and values of locals, is a common argument across multiple contributions. McCullough state that *"[d]igital ground is shorthand for a complex proposition: Interaction design must serve the basic human need for getting into place"* [253, p.172]. And Messeter continue *"[p]lace-specific computing may be described as computing in which the designed functionality of systems and services, as well as information provided by these systems and services, are inherently grounded in and emanating from the social and cultural practices of a particular place, and account for the structuring conditions of place – social and cultural as well as material."* [256, p.32]. This *what* is supplemented by a tentative *how* in Kaptelinen & Bannon's call for localising and supporting intrinsic design. They argue that *"[. . .] people themselves create better environments for their work, learning, and leisure activities"* [193, p.280], and Roger's state that *"[. . .] the inhabitants of ubiquitous worlds should be able to take an active part in controlling their set up, evolution and destruction"* [302, p.412][4]. The turn towards inhabitants as active developers of technologies that fit their local environment and practices is clear. Dourish and Bell openly ask: *"How would a do-it-yourself ubicomp be manifested?"* [110, p.203]. In this dissertation I will attempt an answer.

---

[3] I use HCI to encompass a broad range of specialised areas and sub-fields, including Computer-Supported Cooperative Work, Interaction Design, Urban Computing and Informatics, Ubiquitous Computing and others that have human-computer interaction and the design of interactive systems as a primary subject matter.

[4] The need for end-user development in ubiquitous computing environments is a recurring topic, not only in the work cited here, but also in technology-centric research on software for ubiquitous computing environments [e.g. 2, 81, 197, 364]. It is, to my knowledge, an open and largely unaddressed challenge.

1.2 Research objectives and contributions

The overall research goal of this dissertation is to explore and broaden our understanding of how people appropriate and develop technologies as part of place-based community[5] activities and propose an alternative technological foundation the can support this better in the future. I approach this through two connected research perspectives. Empirically, I examine how a local volunteer-based urban community appropriate and design the collection of technologies they use to organise the community at large and their activities in particular, and in turn how these change as with the community. This community is place-based in two senses. The community and their activities are centred around a community space and their common interest is in locally grown organic food. Hence, with their explicit and implicit identification with being local, it is relevant to study how this is reflected in how they appropriate technology. The research questions guiding this are as follows:

- How do we conceptualise ubiquitous technologies from a community perspective?
- How do the collection of technologies change over time and what are the influential factors?
- How do we characterise these activities compared to existing conceptions of technology use and development?

The contribution from this work is summarised in chapter 4 and presented in detail in Paper II and Paper III. The central contribution from this work is the notion of *community artifact ecology* as a way conceptualising the technologies a community use, own and develop as part of becoming a community and through community activities. This is presented in Paper II. In Paper III we expand on this work from a process perspective. This contributes to our understanding of how the community artifact ecology evolves over time by examining the role of community activities, changing needs and technological progression.

Technologically, I have taken part in the development of four design cases that explore the technological foundation for place-centric computing and different ways of coupling and adapting physical features and artifacts with interactive components. As design experiments, they explore how to ground technologies in particular places, scaffold different types of information spaces and different techniques for binding these to the place and interiors in accordance with how it already structure and filter people, activities, information and access. The research questions guiding this are as follows:

- How can we support place-specific activities with network technologies and bounded local information spaces?

[5] When I use the word community I refer to place-based communities, a neighbourhood community, housing organisations, local associations etc.

- How can we support more adaptive couplings between between physical objects and information?
- How do we support end-user appropriation and programming from a place-specific perspective?

The contribution from this work consist of several technological contributions discussed in chapter 6 on the design experiments. This includes an refinement of the proximity sensors [200] developed in a prior research project [see 59, 205], techniques for coupling information artifacts to places based on network routing, and subsequently coupling participants to information artifacts through network presence. These contributions are part of Paper IV and Paper VI. The work contributions to work on end-user programming in ubiquitous computing environments by proposing an approach that enable users to instrument and develop content and functionalities for their local environment. This is part of Paper VI. The last design experiment examine a closer coupling between adaptive and dynamic surfaces, and then digital content. This contribution relates to the second research question and is part of Paper V.

Additionally, I present a methodological contribution. In Paper I we make an argument for engaging in the development of novel technologies as an important part of socio-technical research. This is summarised in chapter 2 as part of my research approach.

Positioning the contribution

The research presented here draw together multiple positions across HCI, CSCW, Ubiqiotous Computing and Interaction design. The work originates in Weiser's original work on ubiquitous computing [350, 353] and the multiple contributions characterising the ecological turn in HCI [e.g. 94, 193, 253, 256, 268]. It share themes with many traditions and perspectives that could easily be considered related work, e.g. urban interaction design, urban informatics, urban computing, pervasive computing, context-aware computing, community informatics, embedded computing (and Internet of Things) and so forth. I have limited the related work in chapter 3 to relevant work within HCI that discuss place and related concepts. Some of the additional traditions are touched upon as related work in the publications.

The contribution is situated within the ecological turn. This is where I have drawn my research focus and understanding of the challenges. The technological explorations are in many ways attempts at operationalising concepts introduced in the ecological turn and traditional ubiquitous computing [e.g. 125, 295, 350].

1.3 Research context

The PhD project is part of the interdisciplinary Participatory IT (PIT) centre at Aarhus University. The focus on place originates in several related research activities that was conducted prior to this PhD project. My research interest originates in topics within urban interaction design and media architecture. In previous work, I have examined how to develop media architecture for buildings that are still being constructed, based on specific qualities of the place, 3D models, future form, function and characteristics [207], and combined media architecture with civic communication and public data [206]. These perspectives have shaped my current interest in places from an conceptual and technical perspective. The research group I joined when starting my PhD, had already explored various aspects of place-specific technologies in their in the project Local Area Artworks [59, 205] and in discussions around using network technologies to foster local participation [204]. Many of the conceptual and technological considerations originate in this work, in particular the use of WiFi as a familiar infrastructure for creating local information spaces and the locally developed proximity sensing platform [201]. I will return to how these technological perspectives have influence my work in chapter 5.

Chapter 2

Research approach

The research I present here is exploratory at its core. It concerns the exploration of how people appropriate and design technologies in and around the places they inhabit and technological alternatives to doing so. In our field this is often associated with the recent influence from design research and more *designerly* approaches to research [70, 209, 372]. The tenets of this tradition is to engage in the practices of the target discipline as a mode of inquiry, art, design, and lately design of interactive systems, as an approach to producing valuable insights to said discipline. But design and construction of research prototypes of varying fidelity is not the only part of our field that, from my perspective, is exploratory and shaped by being so. It is a recurring observation and concern that HCI is expanding too fast and is a field in the middle of a chaotic multiplicity [50, p.31], in a burgeoning state and perhaps even *spiraling out of control* as Rogers argue [303, p.1]. Whereas this is often discussed as problematic [12, 303], it is also a testament to the exploratory nature of HCI research itself. Theoretical work have expanded to account for aspects of human-computer interaction that the previous generation did not, e.g. Bannon's insistence on users as human actors [19], or McCarthy & Wright's emphasis on the full spectrum of human experience [252]. These research explorations have led to a similar expansion of the methodological repertoire and broader discussions on the role of engineering and design activities, and the prototype itself. Is it a solution, a technology probe, an exemplar or proposal? The state of affairs is a frequent point of discussion in HCI [e.g. 60, 136, 165, 278, 294, 301, 303, 372], and outside[1].

In this chapter I will outline the approach to research adopted and developed in the PhD research. I will start by presenting the overarching methodological position of the dissertation, which is also part of the contribution. This leads to a process perspective and the inner relation between the research activities. The details of the individual research methods are not presented here, for this I refer to the individual publications.

[1] During the CHI 2016 Plenary, Alan Kay characterised HCI as a pop culture that does not take its larger mission seriously. See https://www.youtube.com/watch?v=S6JC_W9F8-g&t=1546s

I recommend reading Paper I before proceeding with the chapter.

2.1 Computational Alternatives

The overarching methodological position, and contribution [see Paper I], of this dissertation is the notion of *computational alternatives*. This concept originates in reading and discussing early works within Scandinavian participatory design (PD). The projects that shaped participatory design in Scandinavia, did so through combining a sociological criticism of technology with the development of socio-technical alternatives [Paper I p.71]. As an example, the influential UTOPIA project was presented as *"[. . .] both a development project for technology and a sociological experiment in understanding the conditions relating to that development [. . .] based on a sociological criticism of technology [. . .]"* [159, p.5], achieved in part by *"[. . .] the development of alternative systems"* [159, p.4]. This have inspired the approach to research developed in this dissertation. Thus, we propose focusing on *computational alternatives* as a way of reinvigorating the concern for socio-technical alternatives represented in early participatory design. In Paper I, we define it as follows:

> *"Computational alternatives are concrete technology, and a concrete practice. They are not new technology detached from a social practice, nor a social experiment detached from critical technological development."* [Paper I p.74]

We refer to computational alternatives as a socio-technical balancing act, as we insist that maintaining both perspectives is important in HCI research. Not as solutions, but as a way of consistently questioning the rationales behind introducing particular technologies as part of our research activities. Computational alternatives share substantial traits with prototypes in the way Lim et al. [229] describe these as manifestations of design ideas. When drawn into research, prototypes also manifest research hypotheses about the technologies and the future practices they help scaffold. The latter is true for design as well, however, we often have future use as our research object as well. Ideally, the design and research hypotheses overlap, but that is not always the case. When collaborating with stakeholders outside a research setting, there is often a mismatch between the aspects of a system that is being researched and what is needed in order to serve the collaboration [see 100]. It is not always easy to serve two masters, as Mattsson & Kemmis [249] point out. With computational alternatives we argue that socio-technical research must question the technological and the design rationales throughout the process, and in particular the taken-for-grantedness that come with increasingly stable platforms. It may be as simple as asking why a research prototype needs to be a smartphone application. Is it because it is a familiar platform, easy to develop for, a prominent device in the target practice or because it *fits* the kind of research questions we are engaged with? And perhaps more importantly, when we adopt particular technologies as components in our research prototypes, we inherent specific conceptions and constraints that may impact the research hypotheses we seek to engage with using the prototype.

Computational alternatives act as mediators in our research activities. They "talk back" as we develop the prototypes and later when they are embedded within specific practices. They mediate between researchers and the technological hypotheses, between users and their practice, and subsequently between research and practice. We argue that in order to be successful in that relation, a prototype must help establish what Engeström's describe as a microcosm – *"[A] social test bench and a spearhead of the coming culturally more advanced form of the activity system* [121]. The setup allow the participants and researchers to peak into alternative futures and engage with implications and potentials in a more direct and concrete manner. It may introduce additional development to fulfill, e.g. supporting domain specific data, integrating other systems and developing components that are needed in order to establish a functioning and credible microcosm. And they often go beyond the research hypotheses, but are necessary foundations for investigating said hypotheses.

With the use of *computational* we seek to emphasise the kind of research and design hypothesis our research prototypes represents. They help us, as researchers, in exploring technologies at an intimate level as part of the process, and in understanding the practices these new systems scaffold – they talk back in process and deployment. As we are interested in developing alternative technologies that challenge existing practices, the prototypes must explore the technological aspects of this. We fully acknowledge the value of prototypes and intermediaries in different formats, but find it important to examine concrete technological hypotheses expressed in the medium in which they will be implemented and used in the future [see 220]. This is where our argument is different than in research through design [209, 372], technology probes [183] and research products [271]. The work that is influenced by research in art and design [130] deals with *designs* on a high level, whereas technology probes are means for collecting data on use. Neither of these positions discuss engaging in exploration of the technologies on a deeper level or producing concrete technological alternatives on a software and hardware level. The technologies they use as examples are seldom sophisticated, e.g. interactive lamps and tables [e.g. 29, 134, 271]. Here we maintain that we *have to* engage with technology development to supplement our empirical and theoretical reflections, to make our research more relevant and connect the different genres and strands of HCI research. I see computational alternatives as an integrative way of combining concepts, theories, methods and models that can link empirical and constructive work, as argued by Oulasvirta & Hornbæk [278, p.4963].

I have used computational alternatives as a way of framing my research and articulate the connection between existing conceptual and empirical insights, the empirical work within the dissertation and then the exploratory design experiments. I have attempted to apply this approach on two levels, as the framing of my dissertation and then in the individual design experiments throughout my work. The dissertation concerns the exploration of an alternative technological foundation for place-centric computing, and in the individual design experiments I have maintained this agenda in parallel with case specific challenges and hypotheses. In each of the design cases, I have spent time developing guiding *research* hypotheses that subsequently guide design hypotheses and implementation activities. As an example, our work on the lecturing system, InPlenary [Paper IV], is driven by a set of research hypotheses that operate on the technological level as well as ideas of the future practices with technology in the lecturing hall.

2.2 Working with theory

Engaging with literature and theoretical work has played a prominent role in my research. However, I do not consider theories as neither explanatory, nor predictive in a traditional sense, and I am skeptical as to how prescriptive theories within HCI can be without the need for 'translation'. I use theories as a way of informing, first my own practice, and then perhaps the practice of others [26]. Halverson [165] discusses theories as tinted glasses that allow certain elements to be foregrounded, while others, necessarily, will fall into the background. As such, I have used theoretical concepts as generative in my work, while also having done my best not to reduce the concepts to mere instruments. I use literature and theoretical concepts in two ways. First, theory guides my work in introducing narratives and critique that have shaped my thinking. Our re-interpretation of Weiser's vision as place-centric in Paper VI is one example, the value position in returning to a localist perspective [e.g. 256, 349] is another. Here, theories, ethnographies and critiques play an inspirational and generative role in guiding further inquiry – empirical and technological – within a larger frame grounded in the work and concepts developed by others. Second, I have sought to apply theory and concepts more directly in shaping the focus of the empirical research and in the design cases. This is evident in the study of a local community [Paper II], where the notion of artefact ecology is taken as the primary perspective in defining the object of study and in the analysis. Similarly, concepts like proxemics and common artifact have influenced the development of the prototypes in the dissertation.

Design as theory building

Developing prototypes and iterating over designs have been a dominant activity in my research. As such they play a double role. First, they are means to a research end, namely investigating how the developed system might change practices and potential tensions in use and deployment. This perspective is covered in computational alternatives [Paper I]. The prototypes also play a formative role in the research process. This is a motivating trait in research through design [209, 372] and Lim et al.s discussion of the anatomy of prototypes [229]. As externalisations of research and design hypothesis they play several roles in the process. They help us communicate with our peers and collaborators, provide clarity to vague or abstract ideas throughout the implementation, and as externalisations they become material for both reflection and analysis [107].

Naur [269] articulate related themes in his discussion of programming as theory building. He argues that programming is first the programmer's building of knowledge, not only about the constructs of the programming language, the compiler and the development environment, but also of the future functions and behaviour, the aspects of the activities and the affairs of the world the program is meant to handle, as he puts it [269, p.256]. Although Naur scope his discussion to a dialectical relationship between the programmer's knowledge as theory of what the program do and should do, his argument captures how I have used development activities to understand aspects of existing theoretical concepts and then how these could be expressed in interactive systems. Moreover, it is an argument from *within*, that discuss programming as a distinct intellectual activity, unlike the more designerly positions that refrain from discussing the act of programming as a mode of inquiry in its own right. In this view, developing and iterating over prototypes are an active mode of inquiry into both the capabilities of technologies and how we can use these to express the high level aspects of place-centric computing.

2.3 An evolving research program

The research questions and focus evolve through the engagement with literature, theories, people and technologies. As to be expected, the research themes and central concepts have evolved within individual activities and across the work. I have used Mackay & Fayard's [237] model of triangulation in HCI as a process perspective to understand the connection between the empirical work, theoretical and conceptual work, and then the construction of design experiments and interactive systems. Mackay & Fayard use their model primarily to understand triangulation within interdisciplinary research projects and in activities closely connected to development activities with multiple participants focusing on a single design and/or domain. In the present case, I have used it to connect multiple activities that do not have an explicit common focus or domain. I did not develop the design cases with or for the community, rather, the insights from the community was translated into the design cases as conceptual constructs. Moreover, in this research the interdisciplinary component does not follow different people with different disciplinary backgrounds, as the interdisciplinary elements are introduced as modus operandi. Mackay & Fayard position design and engineering at the centre with empirical and theoretical work on each side, as they are closely related to the design and evaluation of the central design artefact [237, figure 5]. I have consciously positioned literature and conceptual work at the centre, and then field work and the construction of interactive systems on the outside. Not because I seek to make a strong theoretical contribution to our understanding of place, rather, engagement with literature has played an important part in developing the explicit focus in the constructive and empirical activities, see figure 2.1. It is the conceptual work that bind the other activities together in a meaningful way.

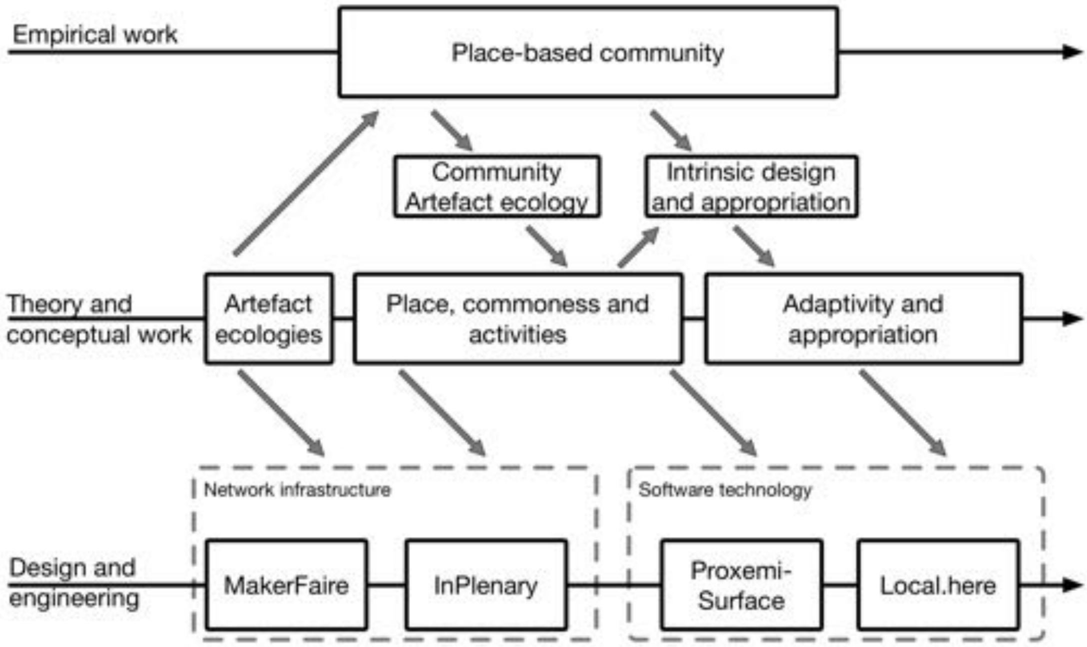

Figure 2.1: The research process depicted in Mackay & Fayard's model [237].

As figure 2.1 shows, there is no direct connection between the empirical work with the design activities (as in the original model), because we decided not to engage in design activities with the community for several reasons. When we initiated the study, the community was already in the process of developing and appropriating technologies when the study was initiated. We did not want to introduce additional technologies into these activities or interfere with their process. Moreover, the community design activities was part of our research objective, so we wanted to avoid a double role. We did discuss the potential for engaging in co-design activities at a later point, but it never made sense to do so from the perspective of both parties. Lastly, on a reflective note, the research interests and the community activities and their articulated needs did not overlap in a way where it made sense to me to engage in designing with and for the community. Therefor, I have consciously maintained a separation and selected the design cases from a different set of opportunities that fit the research agendas better. This does not mean that the perspectives exists in a vacuum throughout the research, merely that the conceptual work and insights from the empirical work have been carried into the design cases as strong concepts, e.g. appropriation and situating development.

Each of the strands evolved throughout my research as a mix of emerging insights and influences across the three. The community oriented research evolved from an analysis of the collection of technologies they use to include the process of appropriating and developing their own web-site. Together with the theoretical perspectives on intrinsic design and everyday messy ubiquitous computing influence the technological perspectives to include a strong focus on appropriation, situated development and authoring toward the end of the PhD research. The design cases developed similarly from a network and sensing perspective, e.g. how to instrument places with proxemic information, to include the software infrastructure that support end-user development and more dynamic relations between physical artefacts and local information spaces. In the two first design cases the network components was the primary motivation for my involvement, whereas exploring software infrastructures that would supplement the network technologies became the focus of the two subsequent design cases. The connections between the different strands are further detailed in the individual publications and the subsequent chapters discussing the empirical foundation in chapter 4 and chapter 5 presenting the design cases.

Chapter 3

Background

In this chapter I return to the background and conceptual foundation for this dissertation. The intention is not to produce a coherent theoretical or design framework per se, but to summarise the concepts that have influenced my research throughout the last three years. For a broader theoretical overviews of on place and space, see [93, 140]. Some of these elements have been explicitly explored and researched, while others are necessary conceptual links. Before diving into place and the important concepts, an brief overview of previous conceptualisations within HCI is in order. The leads to the a presentation the definition employed here and the specific concepts touched upon in the introduction. I will summarise the chapter by presenting the key concepts as a framework that will be further empirically and technologically enriched in the subsequent chapters.

As introduced in chapter 1, I use Gieryn to establish the basic definition of place used in this dissertation. He provides a well-articulated and integrative working definition that avoid giving primacy to a single feature and resist the temptation of producing layer models that imply an analytical division and hierarchical interdependency. Further, we circumvents dualistic discussions on 'space' as the raw environment and then 'place' as cultural interpretations thereof, and subsequent arguments that resort to describing the physical environment as secondary, as means and resources, or tertiary as situational frame and context. Gieryn's definition is a starting point, but it does not adequately discuss how places structure human activities and how a place maintain consistency in human activities across time and individuals. Work on place within Interaction Design have favoured work from human geography, e.g. Tuan [341] and Cresswell [97], perhaps due to the shared inspiration from phenomenology [94, 256]. Two perspectives have dominated the adoption of these theories into HCI: individual experiences of place and space and a concurrent and situational perspective that emphasise place as an achievement of the situational. Human geography discusses the role of underlying permanent material structures [see 256]. This is recognised in the adoption of human geography into HCI, e.g. with Ciolfi & Bannon's *"[p]laces both constrain and enable us: they offer us structural, cultural, social clues that shape our conduct; and our actions and interactions within* *that place add to its meaning and value."* [94, p.222]. However, the vocabulary seems abstract and only provides a few conceptual entry-points, e.g. cues and structuring, as well as hinting at the dialectic nature realised in interactions. Further, the adaptation of human geography in HCI is closely related to work within user- and experienced-centered design [e.g. 94, 251], and thus the developed take on an individualistic perspective.

In this chapter I suggest a different approach, namely developing an understanding of place as an artifact and an ecology from an activity theoretical position. Doing so is in line with the existing definitions used in HCI, i.e. place as space plus something else [e.g. 109, 122, 168, 253] or the adaptions of human geography in HCI [e.g. 94, 256]. Kaptelinen & Bannon develop their focus on technology-enhanced activity spaces on a similar activity theoretical foundation [193]. Doing so adds a cultural-historical dimension, can help explain places as a common artifact shared by members of a community and discuss that places too mediate activities. Further, it allows a balanced analysis acknowledging Gieryn's bundled features, place as geography, material from and culture and the notion of information ecology discussed by Nardi & O'Day [268], while also giving access to an inner perspective, i.e. a place as a particular gathering of people, practices, technologies and representations. I further argue that adopting an activity theoretical framing will help provide substance to the important concept of *grounding* from the ecological turn [94, 253, 256]. This conceptualisation is not explicit in any of the included publications, although the work on community artifact ecologies in Paper II is strongly influenced by earlier work rooted in activity theoretical understandings of the dynamics of artifacts [e.g. 54, 55].

3.1 Place and useful metaphors

Several authors have suggested the use of spatial and placial metaphors in the design of applications for individual use and in collaborative and distributed virtual environments. In the virtual workspace application Rooms, Card & Henderson [83, 175] use the idea of a room as a encapsulation metaphor for a set of tools and applications belonging to a major user task or a specific project. When users switch task, they move to a different room. This allow filtering between relevant tools and information to avoid cluttered work spaces and support consistent task switching. They explore inclusion as a way of nesting tasks and tools, e.g. a room can be inside another room, and the idea of doors as a navigation tool. Roseman & Greenberg [148, 305] continue to explore spatial metaphors and ideas similar to those in Rooms in groupware systems. In their analysis, they provide a a comprehensive list of the features inherent in the room metaphor that go beyond using simple aspects of spatial metaphors [148]. Erickson [122] and Harrison & Dourish [168] provide tentative argument for considering place, not space as the useful metaphor in application design. Erikson discusses how spatial elements might generate, signify and structure interaction, noting that *"[a]n important attribute of space is that people understand a lot about particular types of space – they see meaning in space. I like to use the word "place" to refer to space plus meaning"* [122, p.402]. Harrison & Dourish continue this view an analysis of place that define it as inherently cultural, stating that *"Space is the opportunity; place is the understood reality"* [168, p.67].

Fitzpatrick's [126] work on the locales framework is perhaps the first deep exploration of a theoretical foundation for design of distributed systems that puts place at the centre. Through her work with several collaborative systems and observations on how people used these in their daily work, she realised that the participants' work practices were much more fluent and dynamic, and that they made use of all available resources, without giving primacy to virtual tools. She states that:

> *"Place rather than space is a better way of conceptualising this work environment; that is, place as the lived relationship with the spaces and resources that afforded the group's satisficing communication and interaction strategies."* [126, p.80]

This leads to her suggesting a more place-based approached defined as:

> *"A place-based approach, then, is driven by a clear understanding of interactional needs, exploits the best features of any space, physical or virtual, to meet those needs, and is integrated into the broader context of how people construct and engage with their workaday world."* [126, p.84]

To that end, Fitzpatrick develops her locales framework based on Strauss' notion of social worlds. In the locales framework, the basic unit of analysis is the 'locale'. A locale is the place constituted in the ongoing relationship between people in a particular social world and the 'site and means' they use to meet their interactional needs [126, p.90]. In this, the site and means can be seen as the resources that enable the activities of a group of people collaborating. Although the work foregrounds notions of space and place with the emphasis on locales as the unit of analysis, the perspective overemphasise the role of the social worlds and the moment-by-moment social construction of context, and articulate the physical environment as means and resources external to the activities [see 146, 267]. Pankoke-Babatz [281] make a similar analysis in parallel with Fitzpatrick, but from a different theoretical perspective. She turns to environmental psychology and Baker's work on behavioural settings as a foundation for understanding applications and virtual environments as electronic behaviour settings. She compares the design of electronic behaviour settings with architecture[1], where architects create behavioural settings in the form of buildings and rooms, and their inhabitants shape them according to their individual or group purposes [281, p.26]. In her view, electronic behaviour

[1] Comparing application design with architecture is a recurring ideal, e.g. Winograd [364] motivates the movement from HCI to interaction design by that argument, and Dourish [109] make a similar argument based on de Certeau's work on the relationship between urban planning and everyday use of cities.

settings need to mimic elements from the real world, e.g. creating boundaries, structure and social mechanisms that support mediated collaboration.

In discussing place and space as metaphors for designing virtual environment and computer applications, the work above inevitable discuss aspects of the metaphors that are useful when considering designing systems for environments outside the computer. Three perspectives from this work have influenced the present. First, they all examine different structural elements of the metaphor. Card & Henderson and Roseman & Greenberg use the metaphors to make clear distinctions between what is inside a room and what is outside, and how this can aid use by filtering tools and activities, and maintain some persistence across different tasks. Fitzpatrick is somewhere in between and focus on the resources present at hand and how different social worlds inhabit different places, and Harrison & Dourish and Pankoke-Babatz go a bit further to examine how places structure appropriate behaviour and actions through a combination of a place's physical features and social meaning. Second, they all argue that these features should be supported by design, some by comparing design of virtual environments with the work of an architect, other by creating the meaningful segmentation and supporting users in populating the rooms and locales. Finally, Fitzpatrick's argument for a place-based approach that transcend the virtual environment and emphasise using the best features of both worlds. These perspectives do not lose their usefulness when we move from the virtual environments into the real world.

3.2 Place at work

Several contributions within CSCW discuss place directly or implicitly by focusing on the environment as part of empirical and theoretical reflections. The first emerge when computers and network technology mature and support real-time collaboration. Ellis et al.'s [120] groupware taxonomy discusses systems for group work that span both distributed and collocated work. Here, I will focus on a few studies of collocated work that discuss its spatial aspects. Olsen & Olsen [275] discuss the spatially of human interaction, and how people move, point and orient themselves as part of ongoing collaborative activities. Collocation provide a higher degree of flexibility, access and a shared local context. Olsen & Olsen describe the room, flip charts and whiteboards as the primary collaboration technologies, with information is distributed in the local environment, posted on walls, documents on desks etc. They found that when teams are collocated it is easy to establish a common ground that go beyond sharing local context and culture, it also support a rich spectrum of casual activities that create mutual awareness, tacit coordination and collaboration [275, p.160]. Luff & Heath [172, 232] discuss local mobility in collaborative activities through studying control rooms, building sites and medical consultation. Their work show how individuals' orientations toward shared objects shifts and transforms throughout the ongoing interactions and how shared displays and other artifacts are interweaved with the interactions and activities of others. This is the case in specific locations, e.g. a control room [172] and in wider environments that require bringing artifacts along as part of the activity [232]. Suchman [330] examines how airport personnel use their shared work environment and the episodic transformation of personal and shared spaces in the room. Luff & Heath discuss the ecological flexibility and dexterity of contemporary technologies. They found that portable computers did not support the same spectre of interaction and flexibility as paper records. They argue that computers are part of the furniture, and as part of the furniture, it demands an orientation from the participants, rather than allowing the participants themselves the ability to ongoingly configure the artifact with regard to the shifting demands of the activity [232, p.307]. Østerlund go so far as to argue that documents can be considered portable places, by demarcating communication and collaboration, and by associating specific spaces and times with certain people, people, practices, and meanings [276, p.201].

Bertelsen & Bødker [39] take on a different perspective in their study at a waste-water plant. They discuss the waste-water plant as common artifact wherein workers continuously recreating an overview that enable coordination across the site, and use changing location and observations together with meters and alarms to monitor the state of the plant. They conclude that although the waste water plant is a geographic place, it also contains a continuum of places playing an important role as the workers coordinate processes together. They discuss how workers 'zoom with their feet' as they navigate to specific places within the waste-water plant to acquire information and coordinate their ongoing activities. Unlike Suchman and Heath & Luff [171, 330], Bertelsen & Bødker offer an interesting account that goes beyond studying settings easily observed by a single researcher and discuss the relationship between workers understanding of the site as a common artifact and then the constant need of seeking out information on foot at the large plant. Bardram & Bossen [27] provide an related analysis in their study of mobility work at a hospital. They depart from Strauss concept of articulation work and propose that mobility work as a supplementary concept in that it is an elaboration of the spatial aspects of articulation work. Similar to Bertelsen & Bødker, they describe several levels of locales within the hospital and distinguish these as standard operation configurations (SOC), i.e. spatial configurations of actors, resources and knowledge that allow actors to accomplish their tasks effortless [27]. In this they describe the hospital on multiple levels. The hospital, the individual departments and even movable equipment is seen as particular configurations of actors, resources and knowledge that help the workers coordinate their activities. The authors point to challenges similar to that of Luff & Heath regarding the lacking flexibility of digital records. They can only *be* at very few specific places, i.e. where the desktop computer is located. They point to context-aware approaches and suggest supporting access to *the right documentation, at the right time, in the right place* as a preferable alternative [27, p.156].

With the advent of portable devices and prevalence of network technologies, place became a subject within mobility work [e.g. 74, 215, 310]. Kristoffersen & Ljungberg [215] discuss how different work situations implicates interaction with technology and discuss how workers frequently have to adopt strategies to make place for interaction, because environmental and situational constraints. Brown & O'Hara [74] examine mobile workers that move from place to place, and manage and adapt space to do work. They found that work activities was arranged to make use of the different affordances of particular places in terms of people and utilities. Thus, a place is made distinct and meaningful to the individual in relation to the kind of work activities it supports. Sanusi & Palen [310] study WiFi use in public spaces and how their emergent use change the conceptions of these places and the activities they are used for. They argue that technologies such as WiFi create possible uses of and activities in particular places that are conflict with conventional expectations of appropriate behaviors for those places, such as coffee shops and parking lots.

This work draw attention to how closely coupled activities are to particular places and how they depend on the spatial configuration as part of the activities. Places play a role in large scale activities and coordination across a site, building, floor and room. There is an interesting span between the large-scale and layered places examined by Bertelsen & Bødker and Bardram & Bossen, the changing use of different places in mobility work by use of various places by Brown & O'Hara, and Sanusi & Palen, and then the micro-mobility aspects studied by Luff & Heath and Suchman. Two features are important. First, the nestedness of places and connection to specific functions, i.e. an operating room, within a ward, within a hospital, and the close relationship to specialised activities and practices. Second, their role as a common objects that help workers coordinate and maintain consistency in their practices. Further, the work discuss multiple levels of tensions between the place and contemporary technologies. Luff & Heath and Bardram & Bossen both identify a tension between the flexibility and conditions of mobility work and then the introduction of fixed computers into hospitals. Brown & O'Hara and Sanusi & Palen discuss how personal and network computing have changed aspects of work and how people use and conceive places in relation to these technologies.

3.3 Moving into the physical world

The defining trait of the work in the ecological turn is that it refers to real world environments and relate to the integration of computers into the physical environment. This idea is perhaps as old as computing in itself. Given the monstrous size of the first commercial computers, early work on human-factors was as much about knob and buttons as it was about the ergonomics and practicalities of walking around inside and around the large machines. The computer was *in* the environment and in some cases the environment was constructed around the machines. This is perhaps best illustrated with the pictures from Chapanis' Man-machine Engineering (1965), see figure 3.1.

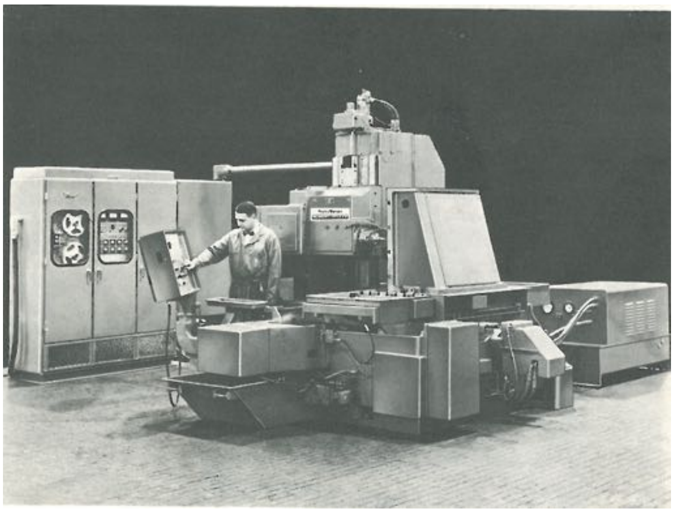

Figure 3.1: Teller machine from [89, p.28]

Krueger [see 217, 218] is the first to explore computing beyond work and the desktop with his work on *responsive environments* in the later sixties and seventies[2]. Through a series of complex installations, Kruger explores various ways in which humans could interact with and receive responses from their environment using computer technology. The room sized installations show-cased several examples where audiences would interact by moving through the space and receive a live audio and visual response through an audio system and projections on the walls. Krueger introduces two important perspectives: First, the foundation for his work is the idea that the ultimate human-computer interface would be at the scale of the body and its senses, and that computing technology *"[. . .] will enter every home and office and intercede between us and much of the information and experiences we receive."* [217, p.433]. Thus, he predicts a reality where computing technology will be a part of the environment and not confined to a single well-known artifact. He moves computing from the display to the scale of the room and into the environment. This is a radical different view on human-computer interaction than the ideas occupying his contemporaries. Second, he take a dialectic relationship between humans and their environment as fundamental. With the use of technology he enable a much more dynamic response from the environment than what walls and surfaces traditionally offer.

Weiser's well-known vision of *ubiquitous computing* represent the next step in exploring the environment as locus for computing [350, 352]. Although Weiser and his colleagues focused much more on work and workplace technologies than Kruger, their

[2] This work represents many firsts in relation to computing and later themes in our field. His approach resemble what would be considered research through design today [e.g. 372]. He refuses a problem-centric approach to technology and explore bodily interaction though the medium of art. [see 217, 218].

vision share many of the aspects of responsive environments. Both visions departed from a human-centric perspective, sought to move human-computer interaction away from isolated devices and into the environment, as well as taking on the task of building technological suggestions in order to explore this new relationship [see 217, 351]. Weiser found it important to construct *"[m]achines that fit the human environment, instead of forcing humans to enter theirs"* [350, p.104]. [351]. Weiser's vision resonated with contemporary researchers and quickly became the frame wherein similar research efforts was positioned. Fitzmaurice [125] used it to talk about situated information spaces where information is associated with physical objects within the environment. The objects act as information anchors and provide logical means of partitioning and organising the associated information space and serve as retrieval cues for users. Ishii & Ulmer persue [185] a similar agenda with their work on tangible bits as a way of bridging between cyberspace and the physical environment. Their focus is on three concepts: interactive surfaces, coupling digital information to everyday objects, and then ambient media. Streitz et al.'s [328] work on cooperative buildings represents a change in focus and scale toward the architectural environment and buildings as inherently serving cooperative activities. Through their research they have developed different approaches to what they call *roomware*, infrastructures that is able to sense who is present and configure the room and devices accordingly, as well as creating couplings between physical objects and virtual counterparts. The ethos is that the real world is the interface to information and that architecture environments become more active and adaptive in supporting activities within [288].

Despite its success, ubiquitous computing still present substantial socio-technical challenges. Seamless may not be an universal ideal and the heterogeneous technologies are appropriated differently within different contexts [see 36, 88, 244]. The (technical) challenges seem amble and the technology-oriented research are still struggling with some of the fundamental concepts, e.g. heterogeneity, discoverability, interoperability, and user interaction [2, 81, 197] and in developing suitable programming frameworks for ubiqioutus computing environments [1, 81, 197] (see Paper VI).

3.4 The ecological turn

With the ecological turn we see an influx of different terms and perspectives to describe the impact of ubiquitous computing, from various positions with diverse approaches [see 193, 303]. Mitchell [259], Nardi & O'Day [268], McCullough [253], Greenfield [150], and Dourish & Bell [110] primarily approach these phenomena from an analytical perspective, where they summarise the trends, issues and potentials, whereas Reich & Weiser [295], Ciolfi & Bannon [94], Messenter [256], Greenberg et al.[149] and Kaptelinen & Bannon [193] direct their work at interaction design. The latter four are influenced by theoretical work in human geography [94, 256], Proxemics [149], and activity theory [193]. Common for the work is a broad investigation of the impact of ubiquitous computing. They all seem to take unset specific places and develop their proposals on various criticisms of technology [e.g. 110, 253, 256] and how these technologies are developed and introduced into place-specific practices [110, 193]. Reich & Weiser [295] discuss *electronic places* as local community information spaces anchored in and around community libraries. With *technology-enhanced physical environments*, Ciolfi & Bannon focus on the interactive systems that enhance and transform the spaces where human experiences occur [94, p.218]. Messeter share the emphasis on grounding with McCullough and focus on *place-specific computing* [256]. Kaptelinen & Bannon [193] discuss *technology-enhanced activity spaces*, and Greenberg et al. [149] suggests *proxemic interactions* as a new approach to ubiquitous computing.

With the ecological turn, the attention effectively shifts from individual technologies to different aspects of the environment. Ciolfi & Bannon [94] emphasise designing for human experiences of place, Messeter [256] and McCullough [253] argue designing *for* human habitats, existing places, and local social and cultural practices, and Kaptelinen & Bannon [193] state that we should move beyond the product and focus on technology-enhanced activity spaces. They all refrain from arguing that interaction designers should design places, rather, they each focus on a subset of a place's qualities and features. However, they all provide suggestions as to the goal of design. Reich & Weiser [295] argue that the network infrastructure should support communities and help preserve local values and characteristics. McCullough focus on the human need of getting into place, which necessarily involves designing for human life, how we move, live and appropriate places for various cultural practices. Messeter state that designs should be able to follow the dynamics of place-making. Thus, *"[. . .] we cannot regard place-specific computing as a finished design [. . .] but as something open for reconfiguration and reappropriation"* [256, p.39]. Reich & Weiser and Kaptelinen & Bannon suggests the most radical of the visions in the ecological turn. Reich & Weiser argue that we need to impose constraints to the Internet architecture to preserve the local substance that makes a place. They suggest proximity based infrastructures that allow *"[. . .] each local community create their own network culture"* [295, p.36]. Kaptelinen & Bannon argue that supporting intrinsic practice transformation is crucial in supporting collaborative practices. They suggest that whatever is designed, should support continuous design and appropriation by those who inhabit the space. As a consequence, Kaptelinen & Bannon point to supporting inhabitants as designers and co-developers of their own technology-enhanced activity spaces *as part of* their unfolding activities. They argue that *"[. . .] people themselves create better environments for their work, learning, and leisure activities"* [193, p.280]. Rogers [302] supplement in her argument for engaging ubiquitous computing environments that focus on proactive people, rather than proactive systems where others define the parameters and context-aware applications. Rogers is clear in the what needs to be developed to support inhabitants in their local activities:

> *"At a smaller scale, it is important to consider how suitable combinations of sensors, mobile devices, shared displays, and computational devices can be assembled by non-UbiComp experts (such as scientists, teachers, doctors) that they can learn, customize and 'mash-' (i.e., combine together different*

components to create a new use). Such tool-kits should not need an army of computer scientists to set up and maintain, rather the inhabitants of ubiquitous worlds should be able to take an active part in controlling their set up, evolution and destruction." [302, p.412]

3.5 A Place-Centric Approach

Now I will turn to the approach that have shaped the work in this dissertation. As outline above, many aspects of work within diverse areas of HCI point toward an integrative definition of place. The works all contribute to highlighting different aspects of place that is relevant to consider. As interactive systems are integrated into the environment, the metaphors developed for virtual environments become even more relevant for situated use. The close relationship between different locales and different activities as well. Across the contributions outlined above, I see a shared orientation toward human activities. Although it is a dangerous exercise to draw a range of concepts into a single perspective, I see strong similarities in the motivation behind the conceptualisation of various aspects of the human environment as behavioural framing [168], information ecologies [268], locales [126], behavioural settings [281], common information space [39], standard operation configuration [27], ubiquitous computing [350], electronic places [295], technology-enhance physical environments [94], and technology-enhanced activity spaces [193], namely the focus on situated human activities and the role the local environment play in supporting and structuring these activities. Thus, a place is the focal point for human activity. As discussed by Olson & Olson [275] and Brown & O'Hara [74], we go somewhere to meet people face-to-face and participate in meaningful activities driven by purpose and intent. Different places support different socio-cultural functions and situations [211, 253]. They are information ecologies, a gathering of people, practices and technologies in a particular local environment [268]. The underlying idea is that meaningful human activities bring together and give meaning to places, and the people and the technologies that are part of these activities, as discussed by Kaptelinen & Bannon [193].

From an activity theoretical perspective [see 41, 194, 266], a place is an activity system, that shape and is shaped by human activities. As human activities have developed historically, so has the artifacts we use and the environments we inhabit. Our habitat and the artifacts that surround us carry with them a particular culture, the historical evidence of their development, the tricks of the human trade as Bærentsen & Trettvig puts it [12, p.57]. As such, artifacts and large parts of our environment can be characterised as crystallised knowledge, where historical practices are incorporated into their features and give places their meaning. Bardram & Bossen provide an interesting analysis of how the hospital has evolved with the practices, and how the particular hospital in their study had undergone considerable indoor rebuilding to accommodate these changing practices [27, p.145]. Places emanate all aspects of the social practices their are crystallisation's of. Their boundaries are defined by this, the doors and walls segment and reflect the division of labour, roles and regulation, and the interior afford certain uses, while discouraging others. In a study, Krampen [211] show how people recognise and are able to name the social functions of particular buildings, factories, schools, offices, homes etc., by viewing photographs of their appearance and layout. Krampen call this the social affordances of buildings. Bærentsen & Tretvigg [12], applying an activity theoretical understanding to Gibson's work, describe these as cultural-historical affordances: The (canonical) uses the environment have intentionally shaped, and developed to support.

Place connects two levels of human activity. The everyday activities and then the longer timescales of cultural-historical change. Lemke [227] introduces two concepts relevant here, *heteochrony* and the *adiabatic principle*. Heteochrony refers to cases where long timescale processes produces an affect in much shorter timescale activities. He argue that *"'[e]verywhere in human culture we find this type of heterochrony: longer-term processes and shorter-term events linked by a material object that functions in both cases semiotically as well as materially"* [227, p.281]. This is the role of the material environment and artifacts, they mediate cultural practices, longer processes and knowledge. The adiabatic principle states that events in the remote past or processes with longer characteristic timescales should have little impact on normal human activity. This does not mean that they are insignificant, rather, we do not register the very slowly varying processes. They appear as a stable background in relation to the pace of everyday human life, subsequently providing stability and continuity across the life of individuals and activities. Places emanate culture, as several scholars point out [162, 168, 256]. Reversibly, small everyday actions and activities affect larger cultural shifts as well. New routines emerge as people change small aspects of their activities, appropriates new techniques and technologies. Activities become actions, actions operations, and operations are externalised into new artifacts [12, 20].

A place-centric approach to computing means that the interactive technologies should, just like the physical environment and existing artifacts, support how everyday activities unfold as people come and go, and how places change over time. Technologies need to be able to coevolve with the activities in the same way that buildings do. This ability to coevolve across longer timescales is, according to Nardi & O'Day, a defining trait of a *healthy* information ecology [268, p.53]. Brand [69] describe how *lovable* buildings are characterised with their ability to learn from their occupants. Adaptivity is crucial in how the built environment evolve and move from freshly built architecture to places with character and history. This kind of activity involve adapting the environment to suit evolving needs, change features and resources to address inconsistencies or simple moving and changing the interior for a specific purpose or event.

As I argue in the introduction and touch upon in the previous section (see also [Paper VI], supporting both everyday activities as they unfold *and* how places and practices evolve over time, is still a challenge in how we envision and construct interactive technologies. Especially when we move outside the hospitals, control rooms, waster-water plants and other well-established places and practices. These challenges are connected to work on end-user development, appropriation and intrinsic design, and technological challenges relate to heterogeneous artifacts, (lacking) interoperability and tools that support ongoing *situated* development. Now I will turn to the three discussions relevant to place-centric computing and influential to the research I summarise in the subsequent chapters.

Changing focus of design

In the related work there is a clear distinction between what a place is and what can and should be a task for designers. Several positions compare this exercise with architecture and argue that designers provide the frame wherein the users, as inhabitants, appropriate the necessary tools in their activities. This may be a relatively simple position when designing purpose built (monolithic) system akin to the early virtual environments. But as we move into the physical environment, the information ecology, designing the environment is rarely an option[3]. When it comes to places, technologies accumulate [253, 299], they follow old infrastructures [145], and are often introduced in a piecemeal manner [116]. However, the analogy to architecture is still useful, because architects do not design places, they design structures that are connected with and *fit* their surroundings [168], structures that become places through how they are adapted throughout their life [69, 253]. This is no different in how information ecologies evolve though use.

Kaptelinen & Bannon [193] propose moving beyond products as the object of design, toward developing activity space-oriented technologies. Several others suggest moving a step down from products and examine infrastructures and tools that support inhabitants in controlling and developing their own ubiquitous computing environment [see 36]. In my work I have operated with a simple distinction. I share the stance that ecologies are not something that is designed, it develops as a result of a plethora of different activities and events (see Paper II). Yet we need something to describe what it is that we are designing or support as the common perspective that can integrate aspects of the information ecology. I refer to this as a common information space, to denote a more integrated perspective and couplings to the vast collection of digital information that pertains to places and their practices. This is drawn from the use of common information spaces in CSCW [39, 66, 314] and similar perspectives from ubiquitous computing [125, 295]. Schmidt & Bannon [314] defined a common information space as *"[. . .] encompasses artifacts that are accessible to a cooperative ensemble* ***as well as*** *the meaning attributed to these artifacts by the actors."* [314, p.28]. and Bossen state point out that a common information space *"[. . .] should be regarded as the result of ongoing processes of achieving mutual interpretations of single items of information"* [66, p.177]. Following this, I see the task for place-centric computing as developing *for*

[3] Amusement parks, movie theaters and other places that have been developed as complete experiences or services are examples where the place itself is designed. They are often associated with discussions on the commercialisation and commodification of public space and placelessness, see [10, 296].

an ecological perspective, and providing the means for better integrating the important aspects of places *into* a common information space that is defined by and accessible for the inhabitants. This change of perspective is visible in the shift from the empirical research in Paper II and Paper III, to the design cases reported in chapter 5.

To this end, Kaptelinen & Bannon [193] suggest focusing on integrative technologies, e.g. meta-tools that allow inhabitants to control and coordinate other tools, and connectors that link different technologies together. Weiser [351] discusses technologies on different levels, i.e. network infrastructure, hardware and software. He introduces a specific software construct, interaction substrates, as a meta-technology that support interaction across multiple devices. It is clear that supporting the development of local information spaces, controlled by the inhabitants as suggested by [e.g. 193, 295, 302], require considering designing for integration into the local information space on all levels, networks, hardware and software. Rodden et al. [300] argue that in order to allow digital devices to be treated as 'everyday stuff' [cf 69] we need to open up access to the supporting infrastructure that connects devices and provides a simpel model that allows them to manage their introduction and arrangement [300, p.73]. I have adopted this focus on infrastructures in my work, as it stand as the adequate level to intervene to ensure interoperability across heterogeneous devices and avoid 'breaking' existing higher level use patterns and expectations.

Scoping participation and information

Although places do not have fixed boundaries or a uniform scale, they are still distinct and often recognisable in name and appearance [211]. Places are nested, as different activities and division of labour have segmented buildings according to the cultural-historical practices they are a product of [27, 148]. This is an important part of how Henderson & Card [175] and Greenberg [148] use the metaphor of rooms in their groupware systems. Here, they use it to associate a particular set of tools with a specific activity, denoted a 'room'. The metaphor is drawn from an analysis of the real world. Greenberg describe how rooms partition space, persist what is inside and provide stability to the activities they support. We see a similar recognition in the work on places as coordination mechanisms in Bertelsen & Bødker [39] and Bardram & Bossen [27]. Physical features are excellent in focusing activities by providing the necessary tools and resources and filtering away what is irrelevant (Henderson & Cards design rationale in Rooms). Proximity and action is closely related. We act where we are and move to interact with artefacts in the environment [168]. Presence and proximity is required for using and participating in specific activities, a perspective that dominates the ecological turn. When people talk about *inhabitants* one must assume they are talking about people who are present within a particular place at a particular time. The notion of inhabitants in the ecological turn indicate presence as a perquisite for participating in place-specific activities and in shaping the environment. Rogers [302] clearly state that the local information space should be controlled by those who inhabit the ubiquitous computing environment. Reich and Weiser describe how local communities participate in and through the local information space. They discuss imposing constraints on the network infrastructure to ensure placeful electronic places *"...so only those who are physically in a community could access some of the community information"* [295, p.36]. Weise et al. [349] suggest similar perspectives in their argument for democratising ubiquitous infrastructure and data. Fitzmaurice [125] discusses situated information spaces as a way to avoid being flooded and overwhelmed by information. He suggest that physical objects anchor information in a way that creates local information hot spots and retrieval cues for the inhabitants.

This introduces two important perspectives in place-centric computing. First, the local information space should be available (only) to the inhabitants and they are the ones who control and develop it as part of participating in place-specific (community) activities. Second, it is necessary to provide means for emplacing information in and around specific local places, as a filtering mechanism so the *right information is available at the right time to those who need it* [cf 27], and as a way of scoping who can and should participate in shaping the local information space. Introducing different layers of presence and proximity, as well as coupling information and interaction to elements of the physical environment have been an important perspective in all the design cases described in chapter 5. This has motivated proposing a generalisable approach to infrastructure perspective in Paper VI.

Between design and use

Harrison & Dourish [168] highlight adaptation and appropriation as an important aspect of making place. Brand [69] discusses adaptivity as an important feature of enduring buildings and Gehl [137] notes that the quality of public space is in part determined by how it can be appropriated for diverse human activity. It is clear that the distinction between design and use is blurring in the ecological turn. Messeter [256] argue that place-specific computing should support continuous re-organisation and appropriation through use and Kaptelinen & Bannon [193] suggest intrinsic practice transformation as a crucial turn away from product centric design. They describe intrinsic practice transformation as the continuous process of adapting all available resources to solve immediate problems in their activities. This, and other work, link how we appropriate aspects of our environment to suit our everyday needs with concepts like end-user development, meta-design, design-in-use, appropriation etc. Kaptelinen & Bannon emphasise that intrinsic practice transformations must originate in the local communities and their activities, and recognise that people already act as designers of their own environment. This echo similar perspectives inherent in the proposition made by Messeter [256] and Rogers [302].

I have approached this as a continuum between design and use. Practices change slowly though everyday use, improvisation, tailoring, appropriation etc. Dourish & Bell [36] describe two messy ubiquitous computing environments that are different in how technologies have become weaved into practices. This happens as everyday use evolves in to different practices over time [cf 227]. In our study of the local community we found a much more complex picture than suggested by Kaptelinen & Bannon [193]. There is a clear difference between when people appropriate resources as part of ongoing activities, and then situations where they turn their attention toward a different object in order to improve the conditions of the activity. This can be cause by a breakdown in a specific activity or as part of getting into place and setting up the tools needed to do something specific. I have operated with a simple distinction defined by continuity and relationship to ongoing activity. In many cases tools and resources get appropriated *in*[4] action and when the recur and become routine they slowly transform practice (following the adiabatic principle [227]). This is use, not design, but over time it may be recognised as idiosyncratic designs (by outsiders). Design is positioned at the other end of the spectrum, where people reflect on their activities and needs, decide to make changes and develop solutions as a conscious activity.

[4] I am borrowing elements of Schön's concepts of reflection in and on action. There are strong similarities with the levels of human activity (and the movements between these) and then Schön's work. The distinction may be useful, but making the theoretical connection is out of the scope here.

Chapter 4

A Place-based community and its Artifact Ecology

In this chapter I summarise the empirical work influencing the notion of place-centric computing. This research exemplifies the kind of community activities and issues that motivates proposing place as a focal point for exploring and developing alternative technologies. I start by refreshing the context of the research and introduce the case. This is followed by a summary of the concept of *community artifact ecologies*. I have supplemented the findings reported in the publications with three additional insights relevant here. I discuss the connection to the technological work by summarising the important technological implications and conclude the chapter by discussing the contribution of the work. For details I refer to Paper II and Paper III wherein this work is reported. I suggest reading the two publications before continuing with this summary.

The purpose of this study was to investigate the collection of technologies that a volunteer-based community made use of in their primary activities and organisation. We hypothesised that common technologies, e.g. social media, emails and online services, played an important role in community work and organisation, as well as in shaping the community activities. We articulated these technologies as a 'community artifact ecology' early in the research process influenced by work on personal artifact ecologies [55, 191], and more place-centric ecologies [e.g. 35, 268]. This influenced our research design and focus, in that we wanted to examine the genealogy of the artifact ecology, the primary influences and how it changed as the community grew and became more established. In Paper III, we explore the various processes of appropriation, improvisation and intrinsic design that have shaped the community artifact ecology and community activities. This research focus emerged slowly with the study and the data analysis reported in Paper II. Throughout the interviews we were surprised on the complexity of the artifact ecology, its many facets and the amount of work the community invested in making it work as their needs changed. Thus, we returned to the data with the goal of understanding these processes better inspired by work on community design [e.g. 193] and infrastructuring [e.g. 287]. I participated in the ethnographic field work by conducting interviews, meeting the community members and visiting the community space in a community meeting and observing their weekly activities. One of the co-authors did further participatory observations as part of her membership of the community. The theoretical discussions and analyses of the data was a joint effort in both publications.

Aarhus Organic Food Community (AOFF) is a local volunteer-based community in Aarhus, Denmark. It was founded by two women based on a similar initiative in Copenhagen, Denmark. It is, as it is tradition in Denmark, registered as an association. This is a common structure for a broad range of volunteer and pastime communities in Denmark. The community is founded around a common interest in organic food, sustainable practices and a desire for local alternatives to existing supermarket chains and selection. At the time of the study, the community had approximately 900 members, and one of our interview respondents estimated 250 active members. The community have a shared primary activity, namely buying and distributing locally grown organic food to their members. This is the focal point for the additional activities, organisation and use of technology. Every week the community purchases organic food products from local farmers, package it in brown paper bags and distribute them to their members. Bags are ordered and paid for on a weekly basis and members have to come to the community space to order, pay and pickup their goods. The community is self-organised and members are required to contribute with three hours of community work every month as part of their membership. The central community activities happen in the community space every Thursday. The community work includ signing up for a packing shift, tending the shop, taking orders, or participate in one of the seven working groups, see Paper II for additional details.

4.1 A place-based community

Although we labeled the community as a local *volunteer-based* community in the study and subsequent publications, it is equally defined by being a place-based community. They share *local* as a community ideal. The community formed around a desire for local, sustainable and affordable alternative to existing supermarket chains. This is expressed in their manifesto [see Paper II], their identity as community and in their activities. They define locally produced as within a 50 kilometer radius of the community space. Additionally, they are place-based in their activities. Every Thursday the participating members gather in the community space, pack, sell and pick up their bag of food. In this recurring activity they work and socialise in the community space. Participation in the community activities and using the service is dependant on proximity. The members are estimated to be primarily local residents in the Aarhus area and you have to come to the community space to become a member, and participating and voting in the open community meetings require presence at the meeting.

The community is also based on volunteer participation, in the weekly activities, meetings and working groups. Around 40 members participate in organising the community and supporting the weekly activity. These members are active members that have contributed throughout the years. At the time of our interviews, the founding member had withdrawn from the board, and another core member had stepped down from a few working groups. The ordinary members are less active. According to our respondents, members use their service once a week, and even fewer participate in the community work regularly. A large part of the member-base seem to buy food from the community a few times now and then, and many do not take more than a few shifts in the community throughout their active membership. Thus, there is a relatively high turnover of participants in the community work activities.

Figure 4.1: Left: AOFF community space. Right: Member packing the weekly bags of food

4.2 Community Artifact Ecology

The concept of community artifact ecology originates in two related perspectives taking an ecological perspective. Jung et al.'s [191] work on personal device ecologies and Bødker & Klokmose's [55] work on their dynamics, and then Nardi & O'Day's [268] work on information ecologies and Bell's [35] related notion of cultural ecologies. The former focuses on the interactive technologies belonging to and in use by individuals, the latter discuss place-specific ecologies, e.g. libraries and museums as distinct information ecologies. Both perspectives insist that artifacts cannot be seen isolated from other technologies (old and new), the activities wherein they are used and the people who use them. Further, they highlight their dynamic and evolving nature as a defining trait. Arguably, the scope increases significantly when we move from an individual perspective to that of a place. In Paper II we define community artifact ecology as follows:

> *"A community artifact ecology is the particular constellation of artifacts that a community owns, has access to and uses in its activities."*

The community artifact ecology and the constituting technologies can be further characterised through the following perspectives. Here I summarise the important characteristics from Paper II and Paper III:

It has an ecology of origin. We found multiple instances where a particular tool originated in the ecology of an core member or similar community, and was introduced into the community ecology to serve a specific purpose. In some cases this appropriation followed the activity, e.g. a member introduces a familiar tool to address a familiar need in the community, in other cases the concrete device changed ownership, as was the case with the donated laptop.

It is stable, yet evolving. The community artifact ecology evolves with the community. Technologies aggregate within the community artifact ecology, as new technologies are introduced, short-term solutions become more permanent and tools that overlap in function co-exist. At the same time there are fixed points of infrastructure where technology meets use and become a stable part of the ecology to a larger part of the community.

It is motivated by internal and external circumstances. The community artifact ecology is shaped by the ongoing needs of the community, either as explicit, strategic decisions or through activity-specific appropriations. The need may be motivated by changes in the community, e.g. increase in members, or problems with the existing technologies. Uncertainty, opportunities and circumstance are both internal and external influences that shape the community artifact ecology, directly or indirectly.

It belongs to the community. The community artifact ecology belong to the community. Some of the artifacts are owned by the community, the website, the community laptop, credit card terminal etc., whereas others have strong links through social media profiles and accounts, a growing collection of documents hosted in various online services and more. While individuals move on the artifacts become part of the community, physically and in their practices.

It is an object of work. While the community identifies with the primary activities, it is clear from the collected data that the managing and developing community artifact ecology became an activity in its own respect. It is a prominent topic at community meetings, the working groups spend time investigating, appropriating and developing part of it, and the primary developer introduce project management tools into the community and participatory design activities.

Influencing factors

The primary focus of Paper III is to understand the factors influencing the community artifact ecology. Here we propose three distinctions in understanding the factors influencing the community artifact ecology and the community activities. *Strategies* are community design activities that are intrinsic to their practices. This type of activities happen in formal meetings and smaller initiatives that initiate activities around specific technologies. *Tactics* encompass the everyday activities wherein the focus momentarily changes from the community work to the community technologies. We identify hacks, substitutions, workarounds and maintenance as examples. *Happenstance* encompass external and internal circumstances and conditions that shape the work related to the community artifact ecology. This includes events, opportunities and 'keystone' community members who volunteer with their technical competences.

As our analyses show, these processes interweave and intersect throughout the lifespan of the community and in the different activities (see Paper III for the details). There is a clear interplay between the everyday tailoring and appropriation practices, the formal decision making and initiatives discussed at the community meetings, and then circumstances and opportunities that continue to emerge and influence their activities. Time and resources play a significant role in a volunteer based community, and so do the competences of the community members. In Paper II we suggest that this is a fundamental trait in volunteer-based community work.

4.3 Supplementary insights

In this section, I will reflect upon and summarise the additional insights emerging from the research. Some of these insights play a less prominent role in the publications, while others have been left out as underdeveloped or because it was sidestepping the central narrative and contribution of the publication. I present them here as tentative reflections and discussion.

Changing needs, changing places

In the publications reporting the work, we emphasise how changing needs motivated different processes in the community. The focus in the publications is primarily how these changes affected the intrinsic design activities and the community artifact ecology. However, the changing needs also motivated relocating the community from their initial community space, to a new and larger space, and after our research was done, they have moved again to a different part of the city.

Soon after the community was founded, they were contacted by a leading member of the youth department of a large Danish political party. She contacted AOFF via Facebook with the following message:

> *"Hey, I read about this and I see you need a place. Should I use my contacts within the Social Democrats and ask them if you are interested, or if you can do something together."* (Laura)

The community accepted, since it was the only option at the time, and initiated their activities in the shared basement with their general assembly January 2010. According to the founding member, Laura, they quickly outgrew the place they shared with the political party. The need for more space was not the only aspect motivation relocating the community. Tension built between the two associations around the management of the shared basement. Laura stated that AOFF felt unwelcome, as they felt using the space was entirely on the terms of the other group. But more importantly, when AOFF started handling and distributing food goods, they needed approval from the Danish Health Inspection, and it became an issue that the space was not kept tidy and that AOFF had little influence on this. Finally, as AOFF grew, they wanted *their own space* to host events, to socialise and support their growing activities.

The community relocated to a neighborhood community centre in the fall of 2011. Here they would have a larger space for setting up their Thursday shop, storage space and facilities for hosting community meetings. This was their primary location until they moved late 2016 to a new location where they currently reside. Since this happened after our study ended, I can only guess as to the motivation. First, they had already expanded their activities at the community centre to include a outdoor container for additional storage space. Through our interviews, the respondents mention smaller tensions between the neighborhood community and AOFF around accessibility, storage, and the need for better WiFi. Second, the new community space is their own, so the circumstances and opportunities might have motivated the move.

It is clear that if spatial needs exceeds what is possible, it is easier for a community to relocated than to expand the existing space. Throughout their lifespan, AOFF has adapted different places to suit their needs, and as the needs changed, they looked elsewhere for a better location. This was not motivated by dissatisfaction with the physical features, but also the social aspects of sharing spaces, different cultures and values, and notions of ownership. Just as many of their technological appropriations was motivated by developing their own identity (see Paper II), so was moving to new locations, e.g. the need to find a community space of their own.

Object of community work and design

The community is founded on a strong common interest in local organic food and sustainable and affordable alternatives. This shared interest is what attracts members and shape how they become a community through activities directed at that objective, but design and technological appropriations played a role in this from the beginning. The founding women spend considerable time designing a logo together with a friend, who is a graphic designer, developing a social media profile, sketching the design requirements to the volunteering web developer and so forth.

> *"I met with him [the web developer]. I just met up with him and then we decided that I should make drawings of what we need. What different panes needed on the page. That was me doing that, designing that. And then Dennis made all the graphic designs and that is the homepage as it is now actually, more or less. All the graphics and all the tabs are the same."* (Laura)

These activities was seen as necessary in order to become a community on the same level as registering as an association, having a general assembly and getting *a farmer, a place and 20 members* (Paper II). However, as the community grew, their needs changed and the existing technologies proved inadequate or never materialised as envisioned, the efforts needed to maintain a working community artifact ecology. This motivated several initiatives around fixing the first website and later redeveloping a new website. This was again undertaken as a collaborative activity among the leading members of the community:

> *"We have been talking a lot about how it should work. What functionalities there should be in the page. I mean, how you are supposed to buy and how you are supposed to take shifts and how, the general design. But of cause Paul has a lot of ideas himself and he is building the web page, so he is doing a lot of stuff by his own design. Currently, like last week and this week, he is having some minor workshop with these particular, specific people about specific functionalities of the web page."* (Robert)

Although the various technologies represent continuous challenges and cause frustrations, it is clear that the community is actively designing elements of the community artifact ecology as a collaborative activity. So while several of the respondents indicate fatigue and frustrations (e.g. Robert cited in Paper II), the community members spend a substantial amount of time and resources in designing and working with technologies as a primary object. This further suggests that whereas the large collective narrative of the community is locally grown organic food, the work in making the artifact ecology work plays a supplementary role in maintaining the community. Learning and gaining experiences in this sort of work was also a motivation for some of the active members we interviewed. Robert sums up in the following motivation:

> *"I got into the work in AOFF gradually. I kinda just got sucked in and kept on joining groups and got various positions, yeah, because I thought it was interesting and I could see that I could learn something for myself as well. That was also part of the reason why I joined, because I could see that I could, maybe not put something on my resume, but I could gain some experience in working in this sort of like, use networking and organising stuff, that I have not done before."* (Robert)

Technology troubles

In the study we saw multiple instances where fundamental aspects of the employed technologies resisted a community perspective or introduced problem in how it was designed or appropriated.

A prominent issue encountered in our observations and in the interviews are the tension between the intangible characteristics of online information, e.g. spreadsheets, member information, and then the place where they are needed. This motivated the introduction of the community laptop, as a way of giving the shifting members access to crucial information in the community space. They needed to register purchases and pickups, access to the manuals instructing them in setting up the various pieces of equipment etc. When members come to make or pickup an order, they are registered by their member number. A frequent issue was that members had forgotten their number and needed to retrieve it when at the community centre. This required them to log into the website, often followed by having forgotten their account information, and thus needing on the spot help in retrieving this crucial bit of information.

A second issue that emerged through the interviews, was the dependency on personal accounts as a way of logging in and accessing community information and services. As large parts of their ecology rely on services that are closely coupled to individual accounts (Facebook, Google etc.), it was at times an issue that a person did not have access to crucial information or functionalities, e.g. a document not being shared or not having access to the admin parts of web services. The elaborate 'hack' described by the second developer Paul (cited in detail in Paper II), was motivated by the fact that the community no longer had access to the back-end of their website. The first developer did not share the admin credentials, which in turn made it impossible for community members to effectively fix and improve the first website, or simply add new mail aliases for new members of the working groups. Even when tools are part of the community artifact ecology, they remain strongly associated with individual accounts and maintain a explicit link to the personal ecology.

Finally, and as discussed in both publications, the community relied on key members with a proficient level of insight into the design and development of technologies. This includes web development, database management, configuration of networks and knowledge on maintenance. This reliance on the particular skills of individuals is a challenge in two regards. First, it create dependency where crucial aspects of the community artifact ecology, and the work it is meant to support. This dependency is a two way issue. On the one hand, developers leaving the community creates insecurity and vulnerability, on the other hand, knowing how much a community depend on ones effort may challenge individual motivations. Second, it may be difficult for other community members to contribute, assess progress and suggest course of action and useful new features.

4.4 Implications for place-centric computing

The empirical work have influenced the focus of the design explorations that are part of the dissertation, see chapter 5. To make the connection, I discuss the motivating implications here.

The emphasis on creating local information spaces anchored *in* the community space is motivated by three observations. First, the community space is the focal point for all the activities of the community. Second, with the frequent change of participants in the weekly activities and the lose patterns of participation, it is difficult to rely on their familiarity with the activity and the necessary information artifact. Third, with the community artifact ecology, the community is building a large repository of disparate documents and tools. These intangible elements should follow the tangible artifacts of the community, the laptop, equipment and the place itself. There is a clear link with what is needed and what Reich and Weiser argue for with his notion of *electronic places* [295].

Constructing technologies should emphasise integration and interoperability, rather than adding new tools and systems to the existing ecology. When discussing the work it became clear to us that the community do not need *another artifact* or a monolithic system. They need means and tools to connect, link and integrate the existing disparate elements of the community artifact ecology and information space. Such an approach should support multiple heterogeneous devices and services originating in peoples familiar personal ecologies as well. Related to this is the argument by Kaptelinin & Bannon [193] for meta-tools and connectors, Weiser's information substrates [351], and the more technical challenges addressed in recombinant computing [116].

Finally, it is important for the community to understand and support their own activities of design and appropriation. The study of AOFF confirms that there is a willingness to engage in complex and lengthy design processes involving several levels of design, e.g. graphic design, web development, database and back-end development. While it is a collaborative activity, the members do not always corporate explicitly. Instead they make small contributions that, over time, amount to functioning tools. Here I see two perspectives: First, lowering the threshold for participating in shaping the community artifact ecology and information space, with familiar devices and tools. Second, situating the development activities *in* the space as well would further support this as a collaborative activity in a community like AOFF. This would support the community aspects of the activity and create a common anchoring point for the individual contributions. Both perspectives are related to the need for end-user approaches to development [e.g. 193, 238], Winograd's [364] move from programming environments toward environments for design, and Rogers [302] call for tool-kits that allow the inhabitants to control, develop and destroy their ubiquitous computing environments.

4.5 Discussing the contributions

The work presented in Paper II and Paper III makes two primary contributions. We introduce the concept of community artifact ecology to conceptualise community technologies as a dynamic and multifaceted phenomenon that is influenced by the members of the community and evolves with their activities. This work is an attempt to conceptualise a previously under-investigated phenomenon that is situated and links work on personal artifact ecologies [55, 191] with community technologies and information ecologies [268]. With this work we add to the growing body of research on how people engage with ubiquitous computing technologies in the wild, something that is increasingly relevant to the ecological turn, and as non-professionals are increasingly forced to and engage in the meta work of making heterogeneous technologies work [36, 193, 277].

We describe the processes and factors that continue to influence the community artifact ecology as members come and go. In this we provide an empirical account on how technology development unfolds in volunteer-based communities. I see this as an empirical contribution that challenge the existing conceptual discussions of intrinsic design, design-in-use, strategies and tactics. This is an empirical contribution to what has largely been developed as conceptual discussions [109, 110, 193], e.g. Kaptelinen & Bannon [193] and Dourish [109]. The research challenge core assumptions in Kaptelinen & Bannon's discussion of intrinsic design by highlighting several levels of extrinsic and intrinsic, continuous and discontinuous elements. As we primarily show in Paper III, the strategic activities are not necessarily closely couple to the community activities in time. Decisions to introduce and develop new community technologies take months and years, while the weekly activities continue. This is exemplified with the work involved in introducing new payment methods, e.g. credit-card and later app-based payment, shows that this work is far from continuous and at times extrinsic to the primary activity [Paper III]. Not surprisingly, intrinsic design of technology-enhanced activity spaces are much richer, entangled and complex than perhaps suggested by Kaptelinen & Bannon [193].

I see this as a related contribution to other works exploring what Bell & Dourish call *do-it-yourself ubicomp* [110, p.203]. Mennicken & Huang's [254] work on how people are "hacking" their habitat, and the emerging studies of the *meta-work* of improvisation, adaptation, tailoring and appropriation that is necessary to make both personal artifact ecologies [277] and community ecologies work [88, 195]. Additionally, it is clear that traditional topics in CSCW on articulation work, coordination and awareness, collocated activities etc., emerge as relevant to work outside traditional work-settings.

Chapter 5

Design experiments

Throughout my research I have taken part in the development of four interactive systems and prototypes that explore varying aspects of place-centric computing and the underlying technological foundation. The cases have each been developed with a particular place in mind, with an onset in a particular set of challenges pertaining to the place and concrete use case. Three of the experiments (I, II & IV) represent a refinement of the technical elements, whereas the third experiment is a broader exploration of designing for adaptivity and dynamic physical elements. Together they represent the evolution of central concepts of the dissertation throughout the process. The cases are introduced separately with a brief description of the context and details of the deployment, the central research challenges and design hypotheses, and then the implementation. I include details on the evaluation and insights from the first design experiment, as it has not been published. I will summarise the chapter by reflecting upon the design work and how it has shaped the focus of my dissertation. The concrete contributions are presented and discussed in the subsequent chapter. I recommend reading the publications reporting on the individual design cases as they are encountered in this summary.

5.1 Technological considerations

As mentioned in the introduction, I rely upon and subscribe to a particular technological focus and specific use components, upon which I have based my own experiments. The decision to continue my research based upon existing technologies are based on a few important considerations.

An important motivation for choosing the technologies in question are based on familiarity to the users and pervasiveness within the domains where we have deployed the interactive systems. Several considerations are important here. Aside from its specific research oriented use, the deployed system should introduce as little technology change as possible. Integration into existing practices without causing disturbances or introducing additional configuration on the client side is pivotal in supporting people who interact with the system. Furthermore, as people bring their familiar personal devices with them, these should be seen as a vital component in how users engage with and participate through the system. Here, I draw upon the general hypotheses from the previous work stating that the use of personal devices create a sense of familiarity and allude to the users existing skills and experience with their devices. When avoiding installing anything on the client device, it is possible to foster engagement through a more seamless interaction. Bødker et al. argue that zero install creates a very low entry barrier for participation and leaves personal devices largely untouched [59, p.767]. Thus, these concerns can be summarised with the following ideal requirements:

- support zero install and configuration on the client device
- use familiar technologies within the domain
- integrate with existing system instead of introducing new

These considerations reflect a research focus, as well as a place-centric approach, that advocate developing integrative technologies and an infrastructure perspective, see chapter 3. I base three of the four design experiments on wireless network infrastructure. There are several motivations for this related to the place-centric computing. WiFi networks have emerged as the primary technology for connecting devices in local area networks (WLAN) and to the Internet. The support is ubiquitous and include a substantial number of household objects, displays and embedded systems (it is assumed that this number will increase with the number of devices being connected [161]). WLANs are interesting in their connection to specific places. There is a strong overlap between particular places and the availability of WiFi networks. Home is where the network hub is [192]. The name of the network (SSID) often reflects the place [see 317], the network is under local control and governed by the institutions where they belong, and their topology and ability to scale with places make them particularly suitable from a place-centric perspective. The technology is flexible and scalable, from home networks, to enterprise and institutional coverage and even city-wide networks (e.g. [273]). As we point out in Paper VI, WLANs are inherently bound to geographic locations, by virtue of signal range and dependency on power. They allow local control, are relative simple to set up and configure, and easy to turn off and dismantle if needed.

The WLAN components are supplemented by proximity sensing nodes in two of the four design experiments. Here I have used the sensing platform developed as part of an earlier project [201]. The proximity sensor work as follows. It captures network packets and extracts the received signal strength indicator (RSSI) from the client device. This signal value is then associated with the client MAC address and depending on the configuration (see the following sections), make this information available through a client-side API. This sensing platform is particularly interesting as it does not require any client aided installation or activation, it can detect any device communicating via WiFi and because it integrates with existing network technologies, it is relatively simple to identify clients and associate their MAC address with an IP address on the network.

There are other technologies that can be useful for instrumenting places, e.g. Bluetooth based systems, indoor positioning systems and GPS as used in location based services. My research does not include a comparison implementation with these technologies. But they could potentially prove useful in supplementing the proximity sensing nodes in future setups, if warrented by the research focus.

Each of the experiments involve developing a software infrastructure for orchestrating and supporting interaction and an application layer through which the users interact with the system. All the cases use web technologies as the primary application layer. This reflects the commitment to using familiar technologies and supporting a broad range of platforms.

5.2 Case I: Aarhus Mini Maker Faire 2014

Aarhus Mini Maker Faire (AMMF) was the first design case I was involved in as part of my PhD. This cases was a collaboration between CAVI, PIT and Aarhus Public Library, Denmark. The design experiment set out to explore how local area network technologies could support collocated interaction between makers exhibiting at the maker faire and the audience visiting the venue. The underlying setup was similar to one explored in a previous project within a local art gallery [see 59, 205]. With the design case and deployment it was our intention to examine two aspects of the interactive system and underlying technologies. We wanted to explore whether the network components developed would scale from the relatively simple setup in the prior case, as well as introduce small variations in how the network was made available to the audience. With the developed application, we wanted to explore how a local information space could support audiences in interacting with the makers based on proximity to their particular exhibition and provide an overview visualisation based on the proximity data. I entered the design process at a late stage and participated in the development of the client-side application. I participated at the event as part of the PIT exhibition and as an observer.

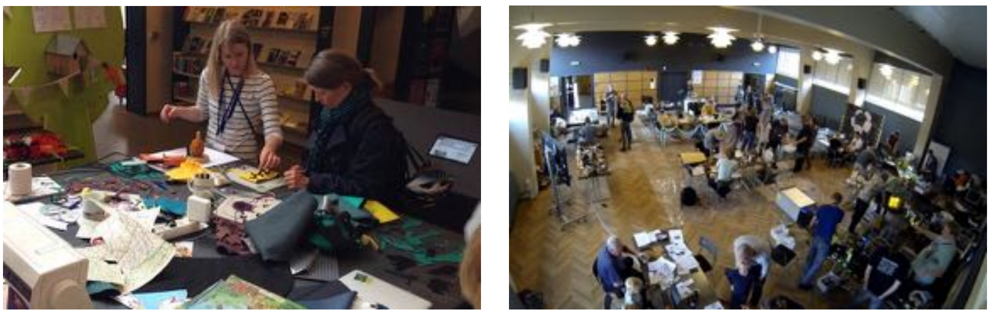

Figure 5.1: Left: Maker booth on sewing. Right: The large exhibition space.

The system was developed and deployed at the main library of Aarhus in May 2014 as part of a two-day event. Aarhus Mini Maker Faire[1] is an annual event, where the library invite makers to come and exhibit their gadgets and technologies, and the audience to come and explore through a mix of exhibition and hands-on experiences with technology. The 2014 exhibit consisted of twenty maker stands and their gadgets distributed throughout the library space, across two floors and outside. A majority of the makers exhibited in a large hall used for public events, while the rest was located in the main library space. The makers exhibited their projects and several stands provided opportunities for the audience to engage in small activities, such laser cutting fabrics and sewing, playing on vintage arcade machines and exploring 3D printers and LEGO robots.

Design

Visitors could use their personal devices to explore parts of the exhibition, interact with the makers and their technologies. When the visitors moved through the space the content would change and show information and interaction possibilities connected with the makers within a given proximity. To use the system, the visitors needed to connect to a wireless local area network established by us. The network was open and all the visitors had to do in order to interact with the system, was to navigate to an URL (her.makerfaire.dk) advertised on posters throughout the space. The design concept was developed for the library space, based on how the staff from the library wanted to adapt the space for the exhibition.

When in proximity of a maker the interfaces would show four panes: About, Play, Talk and Map. ‘About’ would display information on the maker, ‘Play’ was designed to allow visitors to interact with particular technologies exhibited at the maker stand, ‘Talk’ made it possible to pose questions to the specific maker. These questions would be visible to everyone within proximity, even after the asking visitor had moved on. ‘Map’ would show a visualisation of the space and a heat-map generated in real-time based on the aggregated proximity data from the system, see figure 5.2. As visitors moved about the contents of the interface would change and the heat-map would indicate activity hotspots.

[1] http://makerfaireaarhus.dk

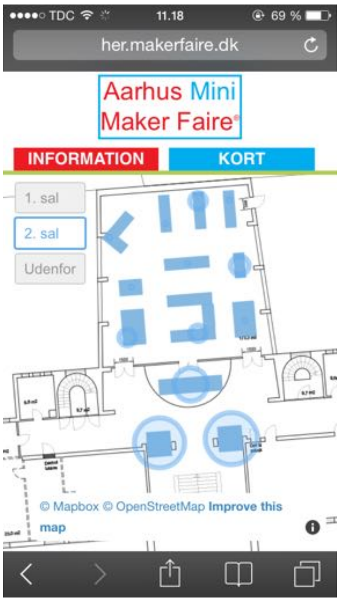

Figure 5.2: Overview map with visualised proximity data.

The ‘Play’ feature served a specific purpose. This allowed the visitors to interact with maker-specific technologies in the instances where the makers had integrated something in their exhibition with our system. The idea was that visitors could use their personal device to interact with a few of the technologies exhibited by the maker. Only two maker stands made use of this. The local arcade gaming association provided a feature where visitors could enter their high-score after trying the arcade machines and we provided a service where the visitors could see a graph of their own proximity data when visiting the PIT exhibition stand.

Technical setup

The technical setup consisted of a network infrastructure, a local server, a software layer for orchestrating proximity detection and associating the maker information with the specific proximity node, and a web application accessible via the network. The network infrastructure consisted of three access points and 20 proximity sensing nodes, one for each maker. Additionally, we offered a small computer (Raspberry PI) to each maker that would allow them to connect their own technologies to the proximity system and web application.

The software infrastructure integrated three components that formed the underlying infrastructure for the web application. The proximity sensors continuously reported the signal strength to nearby client devices to the central server, where the web application could query for the signal strength to the nearest proximity sensor. We used a Google spreadsheet to gather the information on each maker and couple the makers to the sensing nodes. A Google API[2] allowed us to use the platform as part of the software architecture, creating a common interface to the information layer of the system. This allowed a larger group of participants from the project group to update information as needed, without the need for updating the web application, e.g. when a maker was relocated or new sensing nodes was added in the physical space. Finally, the 'Play' page was a small web page that was provided as a small sandbox to each maker where they could develop their own content and integrate elements from their exhibition. This was an individual web-page that was transcluded into the web application.

The web application implemented two levels of proximity. If you connected to the network, but were outside the range of a sensor, the web application would display a dynamic map showing activity zones based on the aggregated proximity data in real-time (see figure 5.2). If within proximity of a maker, the application would show the maker-specific elements of the interface. The web-application was accessible within the local area network. If you would access it from outside the network, you would be redirected to the normal maker faire website. Thus, the system implemented an additional level of presence, namely a global view that would render a standard website and offer no access to interacting with the makers or see the proximity data.

Evaluation and contribution

We gathered data throughout the event. This consisted of video recordings, log data[3], participatory observations and exit-interviews (N=13). We evaluated the project together with the library staff and the participants from CAVI and PIT.

The technical aspects of the setup functioned worked without any significant issues and we succeeded in achieving the technical goals. The system worked, it scaled and performed well. However, very few visitors discovered the system or used the web-application. None of the exit-interviews revealed any use and we only observed use in relation to demonstrating aspects of the system at the PIT booth. The visitors did discover the open access to the Internet, as we saw continuous traffic on the network, but almost none to our server and application. In the reflective evaluation, we posit that people did not use the application because of lacking visibility. There were no visible cues in the library space or at the maker booths. The posters advertising the network had no apparent (indexical) connection to the system. When using the network it did not introduce any elements that would indicate the presence of a *local* network offering something different than what people normally expect from network technologies. The visitors simply used the network as they were used to. Finally, there was a weak integration with the activity itself. The system did not offer anything crucial for participating in and getting something out of the exhibition. This dissonance between

[2] https://developers.google.com/google-apps/spreadsheets/

[3] Due to technical issues, the log data is limited to data from a single day.

what the activity afforded and what the system provided is clear when going through the video material. It shows groups of visitors enjoying the exhibition together, talking to makers, socialising and playing with the exhibited technologies.

5.3 Case II: InPlenary 2015

InPlenary was developed as an internal experiment in our research group. It is a system designed with the traditional university lecture in mind. My co-supervisor, Clemens Nylandsted Klokmose, and I developed the research and technical setup, with assistance from CAVI. I focus primarily on the prototype and the technical setup here, the case is reported in detail in Paper IV. With the experiment we wanted to explore how we might integrate the multiple personal and fixed technologies within the lecturing hall into a situated information space, and use this as a way of supporting active participation in the primary activity mediated by people's personal devices. The work is motivated by three observations. First, the modern university lecture is a prime example of *disconnected* co-located personal computing [Paper IV]. Although both students and lecturers bring their personal devices into the lecturing hall, they are difficult to appropriate for common activities and using these as means of participating in the activity. Second, lecturing and teaching depend on the active participation and construction of knowledge as a collective effort, and this is poorly supported in university lecturing using existing technologies. Third, whereas the physical space have developed through decades of refinement to support the lecture activity (from the Greek theatre to modern auditoriums), the network and personal devices are designed for individual activities and offer ample opportunities for distractions and parallel activities. The *local* area network and virtual environment stand as under-developed in relation to the primary activity. The motivations and research hypotheses are described in detail in Paper IV

Design

In the design we focused on integrating the existing practices around lecture slides. We wanted to support lecturers in adding learning activities to their existing slideshows, and students in annotating and engaging with the slides *in* the lecture, and afterwards as part of their continued studies. We developed several components that were integrated into a web-based platform. This consisted of a preparation component with a slide editor, a lecture component, and a student component for viewing the slides after the lecture was done.

Lecturers using the system would start by uploading a slideshow developed in their application of choice and then add the various learning activities as overlay [see Paper IV]. As they moved to the lecturing hall, they would open the slideshow within InPlenary and then run it. This would create an *instantiation* of the slideshow (a cloned data object) and associate this with the lecturing hall. This association would make the

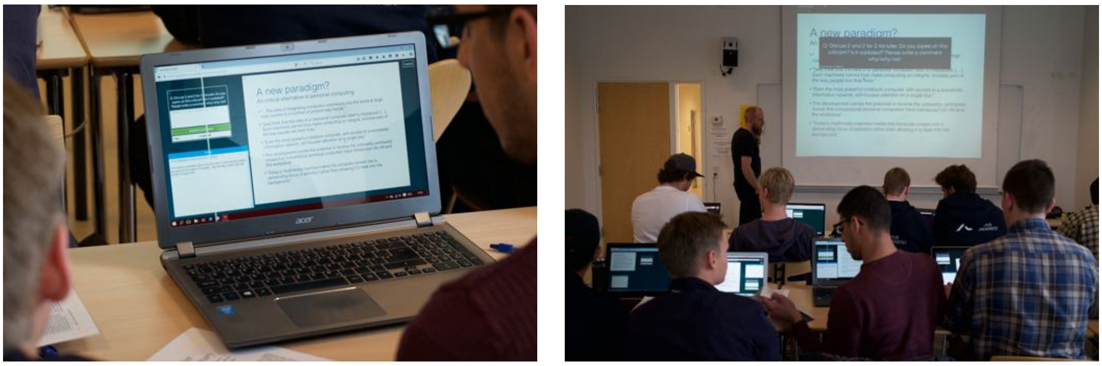

Figure 5.3: Left: Student view: Discussion & notes. Right: Projector view: Discussion slide. [Paper IV]

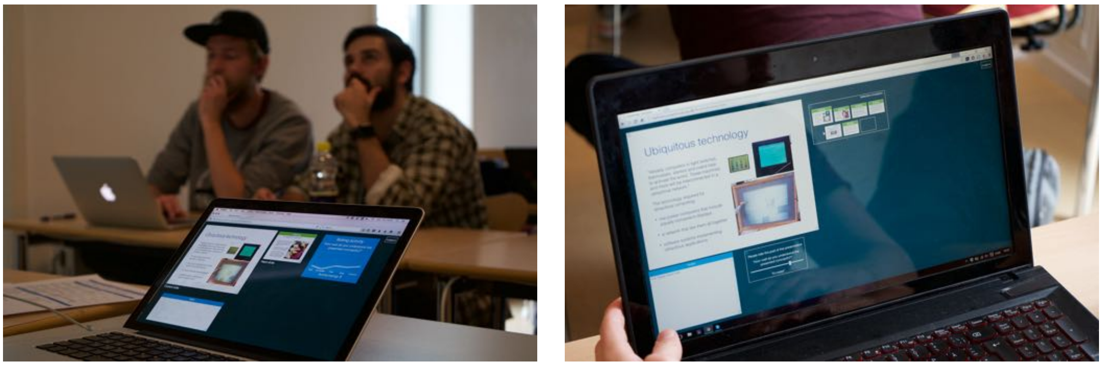

Figure 5.4: Left: Lecturer view: Slides & Rating Right: Student view: Reflection & Rating. [Paper IV]

slideshow appear on the project within the lecturing hall, and make it accessible from any device within the lecturing hall via the local area network. The lecture view shows interface elements akin to those in other presentation tools and the special interface elements associated with the learning activities (status, responses etc.). The student view show the current slide, a large field for taking notes, and when active, a special interface element for each learning activity. When the lecturer changes slides on his computer, the projector would update the current slide and likewise on the student devices. The different learning activities would then allow the students to contribute to the lecture by answering questions, pose questions and reflections, and engage in small exercises where the students would control a subset of the lecture slide. When the lecture ended, the slideshow would be *frozen* in a state where it was no longer possible to change the embedded information from the learning activities and notes. Students who were present on the WLAN and logged into the system at the time of the lecture would have access to the slides *and* the results from the learning activities, as well as their personal notes afterwards. Students who did not attend would rely on the lecturer sharing the slideshow on other platforms.

Conceptualising the lecture slides as the common artifact was an important aspect of the design. When the lecture is instantiated everyone within the lecture hall would be able to contribute through the predefined learning activities and annotate the slides with personal notes. We specifically chose to synchronise the slideshow across all clients as an response to the findings by Sana et al. [309], as a way of focusing the attention on the lecture activity on a device level as well. We implemented familiar learning activities based on insights from related work and two additional to explore how students would contribute more openly in the lecture, see Paper IV for details.

Technical setup

The system consist of a network infrastructure, a software infrastructure and application layer. The network setup consist of one or two access points within the lecturing hall. The projector was connected to the system via a computer and the personal devices likewise through the WLAN. The software infrastructure consisted of a small web-server running on the APs and a service that would associate the clients with the room based on their connection to the network. As the client devices connected to the network and the system, the web-application would query the small server on the AP for an identification code, which would subsequently be matched to a room object via a separate location service. We integrated the university authentication infrastructure[4] to identify users according to their existing profile and avoid adding additional authentication components.

As a lecturer instantiates a lecture from his device, it would be assigned to the room via the location service. The clients (projector, lecturer and students) would then query the system for updates on the room and lecture objects and change the views accordingly. Data from the learning activities embedded in the slides would be persisted on the lecture object and made available afterwards *if* the user had been in the room and connected to the network and system. Thus, the system implemented a simple presence model. If within the room and connected to the network, the user would subsequently have access to the lecture slides.

Evaluation

The evaluation is based on a study of the system in use in four lectures. In two of these we conducted the lecture, while we recruited two colleagues for the remaining two. Following the lectures we conducted interviews with the two lecturers and participating students. For details on the study, see Paper IV. We did a combined analysis of the qualitative data and the data collected from the system on interaction and participation. The technical aspects was evaluated based on simple indicators, e.g. client disconnects, breakdowns and observable issues on the network performance. We did not evaluate academic performance or use of the system outside the lecture.

[4] http://wayf.dk

5.4 Case III: ProxemiSurface 2016

ProxemicSurface is an exploratory prototype, developed with dynamic collaborative work in open office spaces in mind. This work was conducted in collaboration with four other design researchers from the Computer Science Department and the Engineering School, both at Aarhus University. My primary role was to aid the development of the interactive content for the table to demonstrate different interactions and scenarios, and design and build the physical prototype[5], see figure 5.5. This work is a recent addition to the perspectives explored in this dissertation. It is reported in detail in Paper V

Figure 5.5: ProxemiSurface: Dynamic table captured in five positions [Paper V].

The design exploration is inspired by empirical observations made by my co-authors in an open office environment within a software company [see Paper V]. They observed the dynamics of ad-hoc meetings around individual work stations and in shared meeting spaces. The observation revealed different transitions in how workers appropriated the interiors and positioned themselves in relation to the object within the space and their co-workers. The observations revealed a tension between the highly dynamic transition of the workers and the low degree of adaptivity offered by the office interiors. In this case we explore the combination of highly dynamic digital content, a dynamic table, and how this constellation supports different transitions in ad-hoc meetings and collaboration. The empirical observations was carried into the design process through scenarios and we explore these early through various ways of prototyping dynamic behaviour, e.g. body storming and through the use of props [71, 280].

Prototype design

The prototype consist of a shapre-changing table, a projection and tracking setup, and an application layer for developing dynamic content to be projected on the table. The physical prototype consists of two surfaces that are hinged together, two linear actuators, and a custom mechanism that pivots the surfaces as the actuators move up and down (see figure 5.5 above). The table supports multiple positions from horizontal to vertical position. It is designed to support group meetings as a table, individual or team work in

[5] I am a trained cabinet maker and worked as such for 8 years before attending Aarhus University as a student.

the intermediate positions, and group discussions around it in the horizontal position. The different positions allow users to view and move individual and shared content together. A part of the design was to support personal spaces and a shared space to demonstrate different levels of collaboration around the table.

Figure 5.6: Left: Personal and shared territories. Right: Group work in a standing position. [Paper V].

Using a combination of tracking and projection mapping allow us to project dynamic content on the surfaces of the table. This adapts to the position of the table as it moves. We use the web-based system*webstrates* [203] to create the dynamic content for the table. To explore the combination of the dynamic table and dynamic content we develop simple objects that are projected on the surface, see figure 5.6. As part of the work we implemented a set of use-scenarios abstracted from the empirical observations [Paper V].

5.5 Case IV: local.here 2016

local.here is the last design experiment implemented as part of my PhD. This implementation links the technologies and themes explored in the previous experiments. The intentions with this design experiment was as follows: First, I wanted to demonstrate the aspects of place-centric computing in the form of an comprehensive setup and proof-of-concept implementation. Second, I intended to develop a generalisable approach to place-centric computing based on the technologies and infrastructure components developed in the previous experiments. Third, and as I started implementing elements of the system, it became apparent that it would allow people to develop their own information spaces based on a relative simple set of tools and components. In Paper VI we include a short definition of place-centric computing and three key premises, similar to the themes discussed in 3. With the proof-of-concept system I introduce five important concepts.

First, every physical entity is represented by one or more dynamic documents in the local information space. Buildings, rooms, physical artifacts, interactive device etc. is represented by an *information substrate.* In the implementation we use HTML document to represent both places and relevant artifacts (see figure 5.7.

Second, as places are nested and contain what is inside, the information substrates

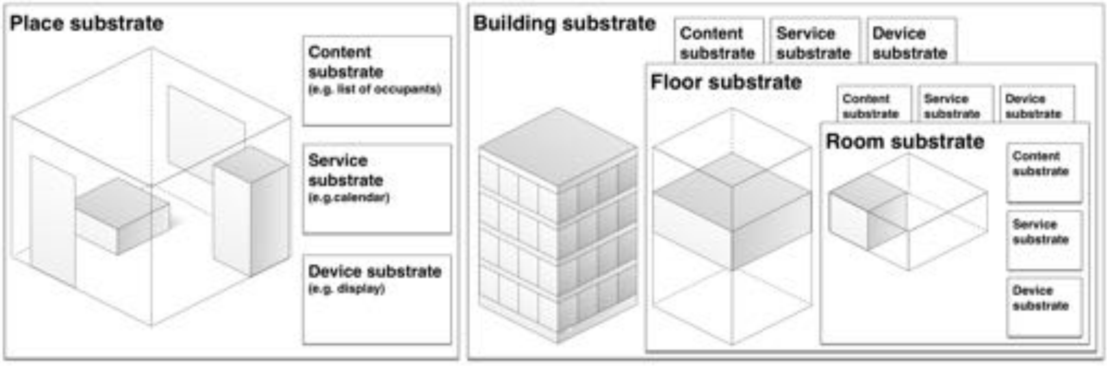

Figure 5.7: Conceptual model: Place substrates: a) simple setup, b) nested setup [Paper VI]

representing physical entities are nested and contained following the principle of *transclusion*. The information substrate representing my smartphone is transcluded into the information substrate representing my office (when I am there).

Third, places are regarded as situated information spaces or information hotspots within a local information space when the place is instrumented with hardware component that couples the place to its information substrate. In the proof-of-concept implementation we use access points and proximity nodes to establish nested information spaces based on the specific topology (see figure 5.8).

Four, we need a generic approach to routing devices into the local information spaces. We propose using the domain suffix `.here` as an approach to routing requests into the local information space. This would provide a universal entry-point, meaning that any client sending a request to `local.here` will be redirected to the information space pertaining to the place. This extension is easy to implement as a supplement to exiting routing and captive portal techniques used to help people discover local web-services (e.g. hotel website). In Paper VI we present four useful routing concepts. Whereas `local.here` acts as the human entry into the local information space, the remaining can act as application interfaces to the local information space, e.g. querying all the present devices by connecting to `devices.here` (see figure 5.8).

Five, by combining the above we propose situating development based on proximity as a model for how inhabitants can establish, develop, control, and destroy their local information spaces [Paper VI]. The system, as it is currently implemented *fully support situated end-user development*. It is possible to approach a place, open a browser, navigate to local.here and start developing content and applications for that particular place using the developer tools embedded in most modern browsers. What is developed stays in the place for the next person to engage with.

In Paper VI we demonstrate the system through two scenarios. An instrumented poster-board where people can interact with the recent publications of our research

Concepts	Generic URL	Wireless LAN	Access Point	Proximity sensor
Place webstrate	http://local.here	place	area	proximity
present devices	http://devices.here	place.devices	area.devices	proximity.devices
local events	http://events.here	place.events	area.events	proximity.events
inhabitants	http://people.here	place.people	area.people	proximity.people

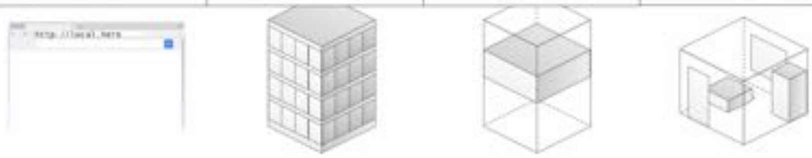

Figure 5.8: Coupling between conceptual elements, entry points and routing map [Paper VI]

group and leave comments. And a meeting room where the large display and Philips Hue is integrated into the information substrate representing the meeting room. This allow participants to change the content on the display without the need of cables and change the lights without having to install a Philips Hue application on their smartphone [Paper VI].

Technical setup

The implementation consists of a network infrastructure, a software infrastructure that doubles as the development environment, and a routing layers. The network infrastructure consist of access points and proximity sensing nodes. The AP expose a small web-server that redirects top level requests to the specific information substrate the AP is associated with. The web server supply an API interface as well. This allow the AP to double as a proximity sensor similar to the dedicated proximity sensors. The proximity sensors have been re-implemented as a decentralised proximity. Aside from the existing sensing software it exposes a small API server on the WLAN, making it possible for any client to query for present devices and its own signal. This allow it to be deployed within the need for a wired connection to an AP or a centralised server orchestrating all the sensors.

The software infrastructure, or software medium as we call it in Paper VI, is based on webstrates [203]. Webstrates serve web-pages as any other web-server, with an important difference. Any changes made to the Document Object Model of a webstrate is persisted on the server and synchronised to all other clients. This particular feature allow clients to change the information substrate associated with a particular place. Developing in webstrates require knowledge of HTML, CSS and Javascript. The routing layer is implemented on the APs and in the individual information substrates. Client-side code queries the available proximity sensors on the WLAN and request the signal strength and the name of the information substrate the proximity sensor is associated with. When the device running the web-browser moves, the routing layer redirects the web-client to the information substrate representing the closes proximity node.

5.6 Summary

Each of the design experiments have had an immense impact on the progress of my research. They have helped me understand and navigate a design space, from learning the core technologies in Maker Faire to providing a integrated implementation in local.here. The progress experienced is not only technological. Each of the design experiments were driven by a set of conceptual perspectives and concrete research question. When reflecting upon the progression of the cases, they stand as continuous approximations toward a concrete understanding of the core concepts explore in this dissertation and the technological foundation for place-centric computing.

Each of the design experiments represent a *computational alternative*. They manifest research questions related to the technologies as well as the concrete practices they punctuate. The clearest example is the research and design rationales embedded in InPlenary [Paper IV]. In the following chapter I will discuss and present the conceptual and technological contributions I see emerge from the design experiments summarised in this chapter.

Chapter 6

Concepts and Technologies for Place-Centric Computing

This chapter present and discuss the combined contributions from the design experiments presented in the previous chapter. Together they constitute the aspects of place-centric computing explored in this dissertation and the technological progression toward an alternative foundation for place-centric computing. The conceptual aspects will be presented first, followed by the technological perspective.

6.1 A place-centric approach

In Paper IV, Paper V and Paper VI we present and discuss the individual contributions of the individual design cases. These are contributions in their own right, here the focus is on the conceptual shifts they represent in the context of this summary.

Making common information places

The design goal across the experiment has been to establish a common information space that fits the place and the primary activities. The information spaces are anchored in particular places within the physical environment and they provide common features to the people who are present and within proximity.

In the Maker Faire case the information space covered the entire building and in the case of InPlenary it was coupled with a specific room that fill a particular function. Whereas the spatial granularity implemented in the system differs, each was connected to the way spatial features segment the place. In the library, the design was setup to distinguish between outside, first floor and second floor, and it provided a more detailed distinction on each floor based on proximity to the individual maker stands. Conceptually, the maker stands were nested locations inside the larger information space provided by the system. InPlenary only offered a distinction between different lecturing halls, as it did not make sense to introduce more granularity or embed the lecturing hall into a larger information space covering the building. The scenarios introduced in local.here [see Paper VI] follow the nested structure of the places. The system support different levels of spatial granularity, e.g. from smaller areas, e.g. a work station or a poster board, to rooms, floors, buildings, and upward depending on the particular topology, they provide a conceptual model for nesting places.

There are several motivations for segmenting and nesting the elements of the information spaces. The goal was to provide information and features that pertains to the specific location because of the link to the primary activity, to couple situated interactions with meaningful information and additional possibilities for interaction mediated by the system. This is similar to the discussions in [27, 40, 125, 175]. At the same time the division functions as a way of scoping accessibility and participation. Maker Faire made it possible to pose questions to makers based on proximity, and in two instances, to interact through certain features. ProxemiSurface is designed to fit how collaborative situations evolve based on who is within proximity, e.g. supporting transitions from individual work to group work. InPlenary only allow students to participate if they are present within the lecturing hall and on the network. The rationale was simple. If you do not participate in the lecture, the discussion and the information embedded in the lecture slide does not concern you. Both Maker Faire and InPlenary suggests local 'read' and 'write', and global 'read' with limitations. Local.here extends this by expanding the capabilities of 'read' to include code, and adds a focus on 'execute', in the sense that being within proximity allows one to execute applications and commands that are not limited to a personal device. The example we use in Paper VI is an interactive lightning system that is accessible via the local area network. When in the room, it is possible to control the lights *and* extend the functionalities of the system by adding custom functions. The rationale for scoping participation is, in the later cases, a direct exploration of how to support what Reich & Weiser's [295] discuss in terms of supporting local community network cultures, accessibility based on proximity and distinct community spaces.

A central part of making common information places is the emphasis on *common*. Whereas the information space itself should be commonly accessible, specific features may be more common and shared across more participants than others. Exploring maker-specific information in parallel is not the same as interacting with and around a dynamic table or participating in the same learning activity. The design experiments each explore this in different ways. InPlenary transforms traditional lecture slides from being primarily a product of the lecturers preparation activity, toward becoming a shared information artifact which all participants contribute to. This is done on two levels. It allows more people to participate in its enrichment trough the learning activity, and it can be viewed and engaged with by multiple devices simultaneously. In Paper IV we articulate it as a common artifact based on Robinson's work [298], but it is more than that, it is also constructed in common as an outcome of the specific lecture. With the work on proxemic transitions and the dynamic table we suggest that the table should support personal territories and group territories [see Paper V]. The manner in which the users work, further suggest the need for moving back and forth between an individual perspective and a shared workspace. Moreover, the table supports this further by being adaptive to the changing constellations. Local.here make a radical suggestion in relation to this. Every information substrate is available to be manipulated, changed and extended by those who are within proximity. Further, local.here makes existing artifacts sharable between those who are present, i.e. a public display or lightning.

There are three entwined contributions to the work in common information places and situated information spaces. With the different designs, I have illustrated different ways of associating information to places and the physical objects they contain. From a building perspective in the case of Maker Faire, to a table in the ProxemiSurface case. This provide different granularity within an information space similar to how Henderson & Card discuss virtual environments [175]. Further, the way a place-centric computing system segments the information space based on these couplings aid in scoping participation and availability. Finally, a core contribution is the distinction between a common information space and the common artifacts as supplementary and interconnected through the primary activity. The information space is commonly available, the common artifacts are objects of both coordination and ongoing work.

Situated between use and design

When adopting a place-centric perspective, distinctions between the activities of design and use become blurred, and so does the roles. Describing these as dichotomies is mistaken. In fact, both should be described on a continuum, where appropriation, tailoring and tinkering is somewhere between design and use, and between the designer and the user are the people who assume different roles depending on their skill and the situation. Each of the design experiments can be inserted somewhere between use and design, and in the similar continuum that emerges when discussing the roles as designer and user.

Maker Faire expands the group of designers so to speak through system components. The project group would contribute with descriptions on the makers and the event even though a common artifact represented by a Google spreadsheet. This does not make a librarian or staff member, who changes a simple title or edits a text description, a designer, but the system allows more people to *adapt* system configurations and the couplings it establishes to entities in the real world throughout the systems life-cycle, and participate in shaping its relation to the place and its spatial features. When a library member of staff moves a maker in the physical space, they are able to make the same relocation in the system. The makers were given a sandbox in the form of an embedded web-page. Although few took the opportunity, it was an invitation to co-design an element of the application. With local.here our intentions are to provide the building blocks for the activities of making a place with technology. This system position the inhabitant in the role of the primary designer in the local information space. Yet, the activity of doing so is likely going to be regarded not so much as a design activity in traditional sense, but more akin to how people already appropriate places and ubiquitous technologies as discussed by [see 36, 277], and exemplified through the empirical work in chapter 4. In InPlenary, the participants are invited to co-construct and contribute to elements within the lecture slides as a shared outcome of the lecture. Again, this does not make participants designers, but they are not passive consumers either. They participate in constructing their learning mediated by the common lecture slides. The lecture slides have been made a more integrated object from the perspectives of all the participants. ProxemiSurface is perhaps the simplest example illustrating adaptivity of the environment as a design ideal. In the exploration we merely introduce adaptivity into the artifact in a way that makes it more situational flexible and malleable.

Each design experiment aim at providing additional capabilities in terms of controlling combinations of physical and digital features. Although one might argue the case, this does not democratise design. It rather allow for the described elements to evolve through present activities and over time. The table is adaptable to how meetings unfold, Maker Faire proved an interesting event infrastructure, and InPlenary has the potential to evolve a given course material with a particular course as more and more lecture slides are added to the common repertoire shared by a particular group of students. Local.here support full-scale programming of ones ubiquitous environment. Brand [69] discuss the 'stuff inside' as what is part of everyday living and Nardi & O'Day a similar scope. People should be able to change and control the stuff inside, including interactive systems and devices. This may or may not call for somebody to volunteer as the indoor decorator or keystone species in making the combined ecology work. All the experiments show different levels of that kind of appropriation and evolution. This is merely a hypothesis, as I have not examined how the systems are appropriated and evolve over time. Yet, the work the community put into making their environment work is an indicator that it will evolve with the activities and some members of a community will assume roles closer to that of users, while others take on the task as designers.

From sandboxes to co-authorship

The most prominent shift represented across the design experiments is the movement from supporting and giving priority to situated engagements and participation, and then moving toward situating design and development within the local information space. In Maker Faire the makers were given a small sandbox where they could develop and insert their own web-page, in InPlenary this took the form of small sandboxes for participation and engagement. Local.here makes the sandbox the entire information space and even integrates physical features, devices and local resources in this.

It has been a goal with all the design experiments to explore different levels of local control and participation – in situated activities and in adapting the environment to fit these activities. The design experiments attempt to lower the barrier for participating in situated activities by using familiar constructs and personal devices as the entry-point.

This was the case in both Maker Faire and InPlenary (and local.here). This is only one aspect of place-centric computing, namely supporting local engagement and participation in the same way a place already does. The second aspect of this involved the common artifacts discussed above. In order to fully participate in activities, one must be able adapt and configure the environment to the changing conditions of the activity. This may be something as simple as moving objects around, producing instructions for the next person to follow, or introducing something new. This is, as argued in the introduction, poorly supported in most current interactive systems. When participants moves from participating in the activity to engaging in reconfiguring the conditions of the activity, they need the means to do so. This may mean reconfiguring parts of the information space. This is illustrated by how the library staff could move makers around in the physical space while setting up for the event, and easily change the setting in the Google document (if having access). MacLean et al. [238] discuss the 'mountain of tailorability' and the differences between a 'worker', 'tinkerer' and a 'programmer'. The task for place-centric computing is to support all of these roles, and if we maintain MacLean et al.'s analogy, to "flatten" the mountain. In their own way, each experiment is an attempt to do so, either by lowering the barriers for participating in the activity, participating in shaping the activity and its constituents, or the place and situated information space that mediates the activity occurs.

The most significant conceptual contribution is in the shift from participating to providing means for co-constructing parts of the place-centric computing environment. Initially through small sandboxes, but with local.here the ability to author ones own environment is expanded to the entire information space, the integrated technologies and the place. This perspective is recent in my research and therefor invites further exploration on both the technical and conceptual side.

6.2 Technological contributions

Each of the design experiments represents considerable engineering and development efforts. Through the experiments I have refined the core technologies, invented new approaches and combined the components in different ways. The progression also represents a shift in my role as designer and developer. In Maker Faire I participated primarily to learn the technologies and their inner workings. In InPlenary I developed the application layer, while being assisted by CAVI on the infrastructure, and in local.here I adapted the technologies from Maker Faire and InPlenary into a much more decentralised infrastructure. I am hesitant in claiming that the technological contributions are novel in a strict sense, because we never intended to develop novel technologies as an end in itself. Several other systems and components resemble those applied here (see Paper VI for a summary of related work), and I suspect that one could implement the concepts developed here in numerous ways using different technologies and techniques. I have followed one particular path based on the rationales outline in the beginning of this chapter.

From a centralised to decentralised

The technical setup in both Maker Faire and InPlenary involved network components that made use of centralised services in order to create the coupling between the locations and elements in the information space. In Maker Faire clients queried a central service to get their proximity and a similar mechanise is employed in InPlenary. In order to support inhabitants in creating and developing (and destroying) their common information space, we needed a complete decentralised approach in local.here. The proximity sensors was re-implemented so that instead of sending the proximity to as central server, each sensor would expose an API server on the local area network for client devices to query. This means that clients need to query all proximity sensors on the network, compare the signal strengths and make the assessment as to which sensor is the closest. The small web-server on the access points developed for InPlenary was modified so that they would handle the redirects on individual AP level and provide a proximity API similar to the sensing nodes.

This contribution has been important in moving from designs that rely heavily on infrastructures controlled and configured elsewhere toward providing means for controlling the local information space where it is deployed. It is a crucial part of the visions and directions influencing this work, in particular Reich & Weiser's [295] request for imposing constraints on the network infrastructure to create more placeful futures and Rogers [302] call for tool-kits that put the inhabitants in charge of their of situated information space.

A generic proposal

In Paper VI we propose a particular use for domains with the suffix `here`. We suggest using this Uniform Resource Locator (URL) as a way for everyone to access local content, information spaces, devices etc. wherever they are. This model allow local information places to evolve in their own particular manner while providing a common agreed upon way of accessing these diverse information spaces. This is similar to how existing universal plug and play (uPnP) protocols, with crucial differences. Whereas uPnP is a communication protocol between individual devices and services, our proposal focus on the information space as the entity that manages the available resources. In traditional uPnP setups the personal device may act as the service finder and aggregate depending on how the operating system implements, detects and provide driver support for the devices it detects. With the work in Paper VI we propose delegating that to the place and integrate existing services and system into the common information space. This would allow people to develop extensions for common devices that are then available to other inhabitants. Furthermore. It is intended first and foremost as a way for people to find their way into the information spaces present where they are, and not as a strict protocol to be implemented solely for device communication purposes. It is a model that support people in making places together and getting into place, rather than focusing on connecting devices alone.

This approach allow people to access the local information space with `local.here`, query local events in `event.here`, insert information about themselves in `people.here` while they are there, and see which other devices are available through `devices.here`. These are just the use-cases we have begun to explore. The list can easily be expanded to include more machine friendly protocols (e.g. with api.here or data.here [see 349]). With the proof-of-concept implementation we primarily illustrate the utility in terms of creating segmented information spaces and how to route people to the local resources . However, it is equally useful from a personal computing perspective, where people are moving between different places, e.g. work and home. In these cases the place-specific URL may serve to create place-aware applications for personal devices, similar to the work within context-aware computing [see Paper VI]. From the perspective of context-aware computing, the proposed approach is related to Winograd's [366] network service model for context-aware computing. The strengths of the proposal made in Paper VI is in its simplicity, as Winograd exemplify with HTTP. This perspective is recent and still open to exploration on the technical level. In Paper VI we focus on the approach from a place-centric perspective, and not from a personal computing or context-aware perspective. As a consequence, the conceptual and technical merits of our approach have not been fully compared with the large body of work within context-aware and personal computing. This is a matter for future implementations to explore.

6.3 Locating use and design

When reflecting on the role the design experiments have played in my research, it is clear that they have shaped my ability to see what should be the ultimate goal of place-centric computing. The full integration of use and design in ubiquitous computing environments. If we are going to move forward with ubiquitous computing, we need to combine the nature of everyday use of ubiquitous technologies discussed by Reich & Weiser [295], Rogers [302], Dourish & Bell [110], Kaptelinen & Bannon [193] and several other, with a technological advancement that support these activities in the places where they are already happening. Our study of the urban community [Paper II, Paper III] illustrate the kind of activities, the timescales, and the complexity and openness of the work involved in this. Here the community member slowly build up a share information space in the form of the community artifact ecology. Its nexus is the place and community activities, rather than individual members or technologies. In Paper VI we explore the computational alternative to the existing practices.

Chapter 7

Conclusion and future work

In the introduction I bring attention to the question posed by Dourish and Bell: *“How would a do-it-yourself ubicomp be manifested?”* [110, p.203], which requires an answer. The reason is that this question neatly capture the overall research goal of this dissertation. My aim has been: To explore and broaden our understanding of how people appropriate and develop technologies together in a place-based community, and propose an alternative technological foundation from a place-centric perspective. I have used the notion of *place-centric computing* as a bridging concept and driver in pursuing these research ends. The proposition in this is that places are ultimate particular, they are the common focal point for human activity, and as computing moves outside work and home, *place* stands as a strong concept in exploring the role of technology from an ecological perspective. In chapter 3, I summarise the related work from within HCI that influence my conceptualisation of place.

The methodological contribution of the dissertation is presented in chapter 2 as concerning *computational alternatives*. With this notion I argue that place-centric computation necessitates engaging with novel practices and technologies in concert. The empirical research provide a foundation for place-centric computing in illustrating the range of technologies involved and the complex practices distributed across multiple actors in time and activity. The design experiments presented in chapter 5 should be seen as an exploration of aspects of the activity of making place deduced from the empirical work. Whereas the empirical work explore the alternative uses of technologies in community organisation and practices, the experiments explore the technological alternatives needed.

In chapter 4, I summarise the empirical part of my research and the notion of place-centric computing through a community perspective. This part of my research answers Dourish and Bell’s question by illustrating how do-it-yourself computing is currently manifested in a place-based community. The central research contribution is an expansion of our existing understanding of how communities use and appropriate tools and technologies. With the concept of *community artifact ecology* we contribute to existing works on artifact ecologies by providing a community dimension. In Paper III we illustrate how the process and work in making the community artifact ecology work unfolds as a mix of happenstance, strategies and tactics.

The design experiments presented in chapter 5 and their contributions discussed in chapter 6 summarise the second half of the answer to Dourish & Bell. This concerns how place-centric computing *could* be manifested with the proposed technologies. The central contribution from this work is the ambition to localise the use and development of local information spaces in and around the particular place it is bound to. The contribution is explored in its fullest in Paper VI where we propose a model for coupling information substrates to particular places, nesting these and a generic routing pattern that make particular information spaces and local resources available through a generic identifier.

The ambition of my research have been to link multiple positions, integrate analytical and empirical insights with technological explorations. Explorations are potent in discovering (and re-discovering) important aspects, but the map it provides is inherently entangled in the landscape explored. I fully recognise the weakness in building from a single case study and focusing on a particular set of technologies. I have insisted on putting the word 'toward' in the title of this dissertation because this describes how far I have come in my explorations. This work opens more doors than it closes and even though the conclusions I have reached with are far from unimportant, there are plenty of research within place-centric computing ahead.

The themes and contributions outlined in this dissertation suggest three avenues of future work. The empirical insights need to be supplemented by additional studies. My hope is that the two publications [Paper II, Paper III] will help motivate others to study similar communities and map the community artifact ecology. I have a research interest in pursuing this further in a Danish context, however, appending local studies need to be supplemented by studies conducted by others in done in different cultural contexts. The theoretical imports and reflections developed within the ecological turn call for further conceptualisation within the frame of HCI and the place-centric perspective driving this dissertation. The tentative introduction of activity theory developed in chapter 3 have been most useful in developing my understanding of place from a more fundamental perspective regarding place linked to human activity. Transforming my understanding into a broader theoretical contribution is a larger exercise, one that I foresee will require additional reflections and engagement with the broader literature. The technologies that provide our groundwork have matured and evolved throughout my research and are now at a stage where we are ready to do a larger deployment in our local context. This will allow us to explore further how local information spaces evolve, how to develop these and integrate a wider range of technologies situated within our own research department. This is scheduled for 2017.

Part II

Publications

Chapter 8

Publication I: Computational Alternatives in Participatory Design Putting the T Back in Socio-Technical Research

Computational Alternatives in Participatory Design Putting the T Back in Socio-Technical Research

Henrik Korsgaard, Clemens Nylandsted Klokmose and Susanne Bødker

Abstract

This paper takes its starting point in a concern that Participatory Design (PD) and PD research have lost interest in innovating and reshaping technologies. We examine decades of projects and the current state of affairs and propose computational alternatives as a means of questioning the state of affairs and reintroducing a technical research interest into PD. Computational alternatives are used to systematically question the technological status quo and peak into a possible future; they are material manifestations of our focus and curiosity and can aid us in inquiring into possible socio-technical alternatives. Ultimately we focus on whether (and how) it is possible to maintain a technological research agenda in participatory and user-centered design, without giving up on pursuit of strong conceptual and theoretical insights.

8.1 Introduction

In the summary of the second UTOPIA report, the authors describe the project as *"[...] both a development project for technology and a sociological experiment in understanding the conditions relating to that development."* [159, p.5]. This socio-technical agenda took the form of a sociological criticism of technology, in particular how it was introduced into the workplace, and based on the criticism the project builds new disciplinary understandings of the development of technology *and* novel alternative systems. The report also lists the envisioned achievements of the project, and the first is *"The development of alternative systems"*. Although there were a strong emphasis on the development of new systems, the contributions from early PD projects that have been picked up by the community focus on the early stages of the design process; involving users and techniques to support this [58, 95, 357], and the (political) critique of and subsequent interventionist approach in development processes and adoption of technology [23].

We can only speculate about the reasons: The publications from the work emphasize the process and participatory centric focus [58, 119] and resonated with contemporary movements in related areas (e.g. [19, 153, 160]). Early PD provided a space for increasingly multi-disciplinary research where a number of non-technical disciplines stepped in and made a home (from ethnography and sociology to e.g. architecture). The movement away from technology as the sole object of interest toward the social conditions of and role of users in the development of technology gave less technical disciplines an opening to contribute and investigate the impact of technology as it spread outside the workplace, a deliberate "branding" of the first PDC [98]. Finally, technology development itself made the "solutions" developed within the projects seem ephemeral to the increasingly less-technical PD community; the methodological (and ideological) contribution were simply more actionable across multiple disciplines, than technical implications and results.

As a result, it seems to us that the interest in doing technological research has largely disappeared from PD research, at an expense of increased focus on process and method. Whereas we have nothing against a design method focus, or for that matter a social science one or an activist attempt to give people a technology they want, we sadly miss a concern also for technology development, technological alternatives, etc. as it was found in earlier years of PD. With the proliferation of the web, mobile technologies, social media, surveillance, data mining, machine learning etc., developing technologies that challenge and expand on existing use and conceptions of technology are more important than ever. This holds both for using technology research as a way of practising a constructive criticism of contemporary computational technology and use, and building upon and from the theoretical achievements of the field. To put it more bluntly, when focusing on process, community building, workshops, participation as a goal in itself, and even "feel good processes" [14], we not only miss out on an opportunity for examining the implications for systems design in detail, we make the theoretical contributions less relevant by not being able to show how our research findings might have an impact on technology design. Our argument is, that in order to do so we need to re-introduce the technology research concern into PD research.

The aim of this paper is doing exactly that, discussing how we might re-introduce a technological research concern into PD, or rather, regain the balance between the social and the technical that is a defining trait of PD, as it was defined in the early projects. We do this through a combined discussion of the historical concerns regarding technological research in relation to PD, the current state of research in PD and in suggesting computational alternatives as a prominent focus for PD research. A computational alternative is, in accordance with the use of alternative in UTOPIA, a (paraphrasing [119, 159]) technical and social design alternative that challenges existing socio-technical conceptions of technology, how it is designed, implemented and used to support practices.

8.2 Socio-technical balancing act

A defining trait of Scandinavian PD in particular is the commitment to socio-technical alternatives. The first generation of projects focused on developing competencies within the workers' unions that enabled these to participate in assessing, negotiating and questioning management strategies for, introduction of computers within the workplace, and develop requirements for future systems. One of the earliest projects [270] were to analyse existing systems in use, the conditions for the workers and the possibilities for the union to influence company operations in relation to planning and control systems, and based on that, develop a system desiderata. In the project they changed strategy from describing the situation and produce proposals, to initiating a process within the Metal Workers Union (MWU) to gather experiences and prepare future action. The MWU project inspired several following projects, DEMOS in Sweden, DUE in Denmark and later a collaboration in UTOPIA. One of the technical-oriented outcomes of the MWU project was the DELTA language [167]. DELTA was designed to support communication between system analysts, people influenced by the system, trade union members, computer programming experts and people working in interdisciplinary teams. DELTA is closely tied to Simula, the first object-oriented programming language [99], the development of which Nygaard participated in. Central to this tradition was the idea (that dated back from Simula's roots in operation systems research) that modelling of human activity had to be a central component in building better systems. However, many experiments with user-centered/driven systems descriptions proved that there is no easy technical outcome of such processes. Simply because these systems descriptions were carried out in a formalism that resembles programming language does not necessarily lead to a good implementation [263].

In UTOPIA, the researchers shifted toward a more offensive and design-oriented strategy. The development of alternative systems came first in the list of objectives, with training and education, and union initiatives as the second and third [119, 159]. The UTOPIA project focused on how the introduction of computers in newspaper production changed the conditions for typographers. Layout computers in the newsroom meant that journalist and editors slowly took over work from the typographers. Researchers from the Swedish Center for Working Life, the Technical University in Stockholm, and from Aarhus University collaborated with typographers in formulating ways in which computers could enhance their skill and quality of newspaper printing. The project outlined *"technical and organisational design alternatives"* that would allow *"a peaceful coexistence between typographers and journalists"* [119, p.171]. The researchers developed mock-up and prototyping techniques that allowed the participants to explore possible future designs and practices. In many ways UTOPIA became famous for its methodological contributions and use of prototypes and workshop formats as the focal point for collaboration among the participants, and to some degree the theoretical contributions, which count both theories on participation in system design and concrete insight on the relationship between work, artifacts and interfaces. Despite developing a system that was marketable and envisioned as a concrete alternative for unions to point to, it is the methods and techniques, and the strong offensive (critical) approach that stands as the primary contribution when reviewing UTOPIA's later influence.

In the Florence project [44, 45], the researchers had two goals: Developing and testing techniques for user participation in systems development, and building a computer system to support the daily work of the nurses. A core concept was the 'application perspective', a perspective that emphasised that computers should be understood in the use context and its value would be demonstrated in use. The basis for the project was that the workers should control the development and use of computers in their work, and that computer systems should be based on the professional language and skill of the users, in this case nurses. Through an approach emphasising mutual learning, the computer scientists were to learn about the practice and daily work of nursing in specific wards, and teach the nurses about different kind of computer technologies. The outcome was two prototypes and a pilot system called the "Work Paper System". The nurses made the specification and the researchers did the implementation. As a result of this approach, the implementation became a technical challenge and the suggestions by the nurses had *"some heavy technical implications"* [44, p.261]. The primary contribution to PD was the idea of mutual learning and collaborative prototyping [72], and the application perspective and its insisting on the importance of professional knowledge and the dependency of the organisational and physical design of the use context. The developed system was in use some time after the project ended, but from the researchers perspective, the system (as a product) was later described as a side effect of the project and *"it was necessary to develop a computer system in order to create a setting of cooperation with the nurses"* [45, p.167].

The Great Belt project aimed at developing more generic CSCW applications supporting large scale project groups. Although having a very technology-oriented goal, the project build upon previous findings and techniques for understanding the context and involving users. In the initial phases of the project the researchers initiated a long range of activities involving participants from the organisation and future users. Through interviews and multiple workshops [see 152, figure 82] the participants and researchers explored the potential issues related to collaborating and managing heterogeneous (information) material in the large project teams. Based on the work, the researchers implemented three demonstrator prototypes including a hypertext prototype. This was developed through several iterations of meetings and feedback with the users, leading to the project's contribution to the Dexter model of hypermedia [154]. The prototype was deployed in a three month pilot-test and saw some continued use within the organisation afterwards. The work contributed with insight into the development of hypermedia systems within a larger organisational context [152] and detailed insights on hypermedia and hypertext concepts [154] in addition to work on augmented paper [236] and telemedicine.

We chose a few of the early examples of PD projects from Scandinavia that exemplify how early PD projects consciously balanced a socio-technical approach and outcome. Reviewing the early PDC proceedings [258, 265], it seems that these examples are unique, with rare exceptions, e.g. Trigg's work in the Workplace project [152]. They illustrate and share qualities of a socio-technical research perspective we take inspiration from and find missing in current PD research. First, all the projects made an effort in presenting socio-technical agenda as part of the research focus in the initial project descriptions. In one end of the spectrum the MWU project wanted to examine the conditions governing the process of adoption of technology in the workplace and develop what could be characterised as specifications for an ideal system, and in the other end, the Great Belt project had an explicit technological focus but did employ and contribute to experiences and the understanding of PD processes from the earliest projects. Second, all the projects made contributions to our conceptual and theoretical understanding of PD processes and techniques for involving and co-designing with future users, and with concrete technical systems and knowledge. In some cases (e.g. Florence) the technical systems "remained" within the context, while in UTOPIA and Great Belt the findings were more widely reported. Third, with the exception of NWU, each project deployed systems of a fidelity that allowed interaction, pilot studies, technical experiments and analysis beyond simple prototypes.

Although the UTOPIA project might be most known for the "cardboard computers" [119] to some, the researchers did develop prototypes of a high enough quality to examine new ideas related to graphical user interfaces and interaction, hence positioning themselves in upcoming areas of image processing and human-computer interaction [118, 332]. Before the era of freezing of raster-graphical displays and desktop computers into icons, windows and menus, the UTOPIA project explored a model that would provide the best possible quality of text and images on the display, while providing tools for graphical users to utilize their professional skills, using lenses in addition to a wide selection of custom-designed, alternative mice/pointing devices.

8.3 The missing technology focus

Some attention has over the recent years been given to the integration of PD with those of software development methods such as agile development: Whittle reviews five PD projects and concludes *"Curiously, whilst there has been some research on adopting PD practices and principles within software development, there has been little consideration of incorporating agile methods into PD."* [357, p.129]. Together with others he focuses on software method integration rather than development of innovative technological systems, tools and platforms as such. Mogensen & Wollsen [260] however, work to expand PD processes beyond early analyses and methodological concerns. Pilemalm & Timpka in their analyses of generations of PD projects within health point out that *"An initial focus on needs analysis and requirements leads to technologies remaining abstract in the PD process."* [286, p.332]. Prototypes may improve on this situation, there are no recent examples (or very few) asking if these prototypes raise technological research challenges beyond software development methods. In reviewing the PD literature from

2002 to 2009, Halskov & Brodersen [164] identify 9 out of 101 publications with focusing on technology, indicating a trend in the community similar to [286, 357]. Balka argues that *"within the PD community we have gotten so focused on processes of participation, that we have forgotten about project outcomes."* [14, p.78]. To which Whittle adds: *"The charge to the PD community is that participation has become "a goal in itself" and has led to an obsession with methodologies for engendering participation and a willingness to see success in terms of "feel good processes" rather than any long-term, sustained outcome."* [357, p.121]

The field of Human-Computer Interaction has in the last two decades seen a decline in research contributions based on interactive systems development and architecture. Olsen argues that *"[t]here are three reasons for this decline in new systems ideas. The first is that, unlike those early days, there are essentially three stable platforms (Windows, Mac, Linux) upon which virtually all software is built and those platforms have dictated the user interface architecture. This is in contrast to the state of UI research 15 years ago when there were many competing toolkits and platforms. The second is that the stability of these platforms has lead to a new generation of researchers who lack skills in toolkit or windowing system architecture and design. The third reason is the lack of appropriate criteria for evaluating systems architectures."* [274, p.251] We believe a similar analysis is in place for the reason of a decline in PD projects with strong technological contributions. The stability of platforms (now also including iOS and Android) together with software that has matured for decades (Microsoft Word (33 years), Microsoft Excel (30 years), Adobe Photoshop (25 years), MatLab (32 years) to name a few) has led to an entrenchment of software practices and a conservatism both on the behalf of software developers, designers and end-users but also in the training of researchers and practitioners in our field. This means that it is easier to build upon available platforms and applications, than to critically rethink whether the entrenched practices are suitable or just taken for granted. Although there are arguments for basing solutions on existing frameworks within the user domain (integration, sustainability, familiarity, licensing etc.), this development comes with implications that are important in PD research. If technologies are chosen based on the researchers' (and users') taken-for-grantedness, familiarity and/or convenience, and later result in recommendations for, or, a finished system, it must be implicitly assumed that our current technologies are adequate for local practices. For this reason alone, we insist that alternatives are needed. Alternatives help both users and designers imagine beyond the taken-for-granted. Uncritically adoption may make researchers and user insensitive toward the ideological premise embedded within the (commercial) platforms discussed above. To us, this stands in opposition to the original ethos of Scandinavian PD, where the local knowledge of professionals are the focal point and the importance of questioning the conditions under which technologies is developed and introduced.

8.4 Computational alternatives

Now we turn to the notion of computational alternatives as our approach to incorporate and start thinking systematically about the role of computational artifacts in PD research projects. At a first glance, the arguments presented in this paper could be seen as a technology-driven. This is far from the case. Rather, we find the balancing act between understanding the conditions where under technology is produced and used, its relationship with practice and the passion for exploring socio-technical alternatives present in the origins of PD an ideal position. But reviving these positions requires, for the present, investigating the role computational artifacts and novel technology may play in PD research. The research we do and our position are strongly embedded in, and shaped by, traditional Scandinavian PD, as we have discussed. To us, PD is not a 'toolbox', a collection of design techniques or a matter of choice; it is the modus operandi, a tradition in the strongest sense. This is why we are concerned with the early PD projects, which considered technological alternatives as part of PD research. In addition we believe that it is actually from within the tradition itself that we get the help needed to understand the role of technological research in specific processes and projects.

In continuation of [52, 152, 155, 220], we see prototypes as computational alternatives in our research practice, developed iteratively in specific cases and more generically beyond that [152, 155]. When a prototype serves as a computational alternative it raises questions, and makes us see what *is* in a new light. A computational alternative is not designed to showcase a new technical solution to a well-known problem, but to elucidate problems in the otherwise taken for granted. Wartofsky [347] refers to artifacts with such qualities as 'tertiary' artifacts; artifacts that make us see possible worlds alternative to the actual world. These 'worlds' are simultaneously connected to and inseparable from the artifact and its use, and the practice they are embedded in throughout a research project. Computational alternatives are concrete technology, and a concrete practice. They are not new technology detached from a social practice, nor a social experiment detached from critical technological development. To understand this further we will now examine computational alternatives as a prototype, practice and mediator.

Computational alternatives as a prototype

Computational alternatives are prototypes in the simplest form; they are the first of their kind and an attempt for explore and formulate an alternative to an existing product, system and/or activity. Just as prototypes are *"manifestations of design ideas that concretize and externalize conceptual ideas."* [229, p.5], computational alternatives are manifestations of alternative ideas on how technology is currently used, like we have seen from many of the historical cases. They question what is otherwise taken for granted, or demonstrate what can be made possible with technology from a perspective of use. This includes questioning how the conceptual models are translated into a system through design choices, and exploring how both existing models and novel alternatives can act, in generative and exploratory ways, as a *"catalyst to elicit good ideas and promote a creative co-operation"* [127, p.6]. This is a familiar perspective on prototyping in PD. Kyng [220] discusses prototypes (and mock-ups, scenarios and other representations in the design process) as representations of the system being designed *and* representations of the the future use. In discussing the difference between low-tech prototypes, he points out that while these low-tech tools and techniques allow users to take on an active design role, the final system will be implemented in some form of computational system. Thus, it is necessary to be able to manifest the ideas of alternative use and alternative computational design in actual computer systems throughout the process. Lim et al. [229] provide a framework for understanding the needed fidelity of the prototype and what components of the prototype needs to be developed in order to examine the qualities and ideas in which the designers are interested. In their framework they focus on prototyping as framing and exploring a design space, where the purpose is not to identify or satisfy requirements but finding manifestations that in their simplest form filter the qualities in which designers are interested, without losing focus on the understanding of the whole. They are for traversing a design space, *"leading to the creation of meaningful knowledge about the final design as envisioned in the process of design"* and they *"are purposefully formed manifestations of design ideas"* [229, p.3]. They emphasize the economic principle of prototyping whereby *"the best prototype is one that, in the simplest and most efficient way, makes the possibilities and limitations of a design idea visible and measurable. If we keep the economic principle of prototyping in mind, determining the values of the manifestation dimensions – that is, the materials, resolution, and scope of the prototype – can be approached in a rational and systematic way."* [229, p.3]. With this in mind, the fidelity of a computational alternative is filtered by what we want to investigate and what it should convey from a research perspective. Not only must a computational alternative have a high enough fidelity to establish a credible practice in order for users to be able to experience and assess the proposed (work) practice represented by the prototype, the level of fidelity should also make it possible to assess the value in the alternative computational aspects of the proposed design. The socio-technical research agendas we describe here, may require that we have underlying systems in place that hold more in common with a finished product than a traditional prototype.

Computational alternatives as practice

As discussed above, prototypes both represent concrete design ideas related to the form and function of a particular (future) system and, in more subtle ways, its future use and ideas about the practice wherein it will be inserted. They represent a specific understanding of the existing practice and possible future changes. In representing possible futures to participants and researchers, computational alternatives serve as Engeström's springboards: *"A springboard is a facilitative image, technique or socio-conversational constellation [...] misplaced or transplanted from some previous context into a new [...]"* [121, p.287]. Springboards do not come about smoothly or automatically, and they are not as such solutions to a problem that one is facing. They are starters that may lead to an expansive solution. Bødker & Christiansen [52] use scenarios as means of making hypotheses or qualified guesses about the future computer application, as embodiments of it. While they consider scenarios as the backbone of design, they also see them as closely interlinked with prototypes that facilitate this embodiment. Whereas much has been said about social and psychological expansion in relation to design and prototyping [38, 48, 121] the focus on technological expansion has been considered much less. The notion of springboards and the idea of facilitative images, transplanted into new contexts, however, allow for thinking about building technologies not only to replace existing ones, but also to take a known technological idea from one context and explore it in a new, possibly without the concern that it should or could ultimately provide the final solution to a socio-technical challenge in the new context. Nonetheless, the fundamental challenges of understanding and developing computational alternatives could usefully be understood as part of such expansion, and hence as springboards in research as well as in design (which is the role in which they have been considered so far).

A computational alternative establishes a microcosm, which Engeström in his work on expansive learning defines as *"[...] social test bench and a spearhead of the coming culturally more advanced form of the activity system. The conscious formation of a microcosm as a sub-step of expansive research corresponds to the formation of a vehicle for transition from cooperation to reflective communication. In other words, the microcosm is supposed to reach within itself and propagate outwards reflective communication while at the same time expanding and therefore eventually dissolving into the whole community of the activity."* [121, ch.5]. The microcosm allows a community of potentially diverse stakeholders to peek into an alternative future, and importantly for us researchers, to study this potential, alternative future, its socio-technical tensions and possible resistances towards it.

Computational alternatives as a mediator

Computational alternatives become instruments mediating use [34, 72] as well as design and research, and in this mediation lie both facilitation and resistance or backtalk. Backtalk is a double loop where the technology talks back in the use situation and then in the research process. But not only that: Computational alternatives talk directly back to research, through the technological challenges that are to be addressed in order to develop a somewhat final and self-sustained prototype that may work in the use situation. One may say that it is in the meeting and confrontation between the double-loop and the direct mediation that the interesting happens for the kind of research that we address here.

Béguin talks about how various forms of mediation punctuate mutual learning in a design process: *"Semiotic mediation occurs when a symbolic language is used to generate graphic descriptions such as maps and diagrams. But mediation also comes in other forms, such as scale models, mock-up, prototypes, etc. [...] Let us call these productions 'intermediaries' insofar as they link the individual and collective dimensions of design."* [34, p.713]. Béguin primarily discusses prototypes and technology probes as design intermediaries, yet we argue that they are also research intermediaries because, in the way he describes it, the researchers are also designers, who set out to build technologies that are instruments for the researcher, albeit driven by a different type of ideas, or rather questioning those. With the notion of 'punctuating' mutual learning he uses a term that on the one hand talks about disrupting mutual leaning, on the other about bracketing and closing something with the purpose of mutual learning. Bødker states: *"Thus, I propose another dilemma: Design representations must be sketchy and incomplete to be used here and now (the napkin); yet to hold on to history and to be handed over, they need to be complete and rigid. To paraphrase Brown and Duguid [76], they need to (re-) create the context of design."* [48, p.118]. With this in mind we are concerned with prototypes that are in a state and quality that can create punctuation in both understandings of the term. They are intermediaries rather than versions of a final system, and help establish a microcosm. At the same time they are also prototypes that are open as to be redeveloped both technically and in relation to use. From the perspective of the concrete prototype, constructing a computational alternative may involve going beyond how we, in a design process, typically use low-fidelity prototypes, or even beyond high-fidelity prototypes, into prototypes that have a fidelity high enough and a scope that is large enough to establish a convincing microcosm for study. This does not mean that the computational alternatives are fully-fledged systems, rather that they are punctuating intermediaries.

In summary, computational alternatives are prototypes setting out to elucidate problems otherwise taken for granted, through concrete technical development. They are manifestations of research and design ideas as well as demonstrations of possible ways to move ahead. They help provide springboards to carry out technology-supported expansion of user practices. They are part of exploratory research processes, rather than versions of a future system. They are functional in particular microcosms, at the same time as they support the investigation of more general alternative futures. They provide backtalk and punctuation, and not least are they the simplest means of filtering and manifesting alternatives of a specific use setting.

8.5 Cases

Local Area Artworks

Local Area Artworks (LAA) [56, 59] was developed to study how information technology could support audience participation in interpreting and curating an art exhibition. LAA was part of ongoing research in how to apply existing technologies and infrastructure, i.e. personal devices and local area wireless networks, to support and enable participation at large. With LAA, a part of the usual curatorial activity of authoring interpretive descriptions for artworks was opened up for the visitors, artists, curators, staff, etc. to participate – effectively anyone physically present in the exhibition space. Hence, LAA made the existing interpretative role of the audience explicit and visible by enabling co-interpretation among audience members in the physical space. A central idea was to use people's personal devices as a means for participation, to create a sense of familiarity allude to visitors' existing skills and experiences with their devices. LAA was developed in dialog with artists and staff at the venue, and through these dialogs an idea was formed about Wikipedia-inspired collaborative authoring in and about a local space. The staff of the art venue, furthermore, shared an interest with the researchers in anchoring a digital layer to the local space and in this project the digital layer consisted of the interpretive texts associated to the artworks. The installation was deployed and ran for the duration of a month-long Easter exhibition at Kunsthal Aarhus in Aarhus, Denmark and was connected to six selected artworks.

In LAA, the conventional curatorial descriptions of artworks were replaced by texts on digital panels collaboratively written and rewritten by visitors during the exhibition mediated by their own personal devices. Using WiFi proximity detection, the system detected when visitors were in close proximity of an artwork and redirected their web-browser on their personal device to the respective editable text [200]. Making use of personal devices can require significant bootstrapping on the side of the user in the form of downloading and installing apps. In LAA we wanted the barrier of participation as low as possible and required zero installation on the user's device. We hypothesized that contributions about local matters would flourish best when people write about what they immediately see and experience. This led us to a design requiring physical proximity of the user to an artwork in order to allow editing its associated text thereby strengthening the coupling between physical and digital layer. Therefore, LAA sought to make navigating between different artworks in the exhibition as 'automagic' as possible by basing it on the user's location in the gallery. Finally, the digital panels next to each artwork gave the digital activity a physical representation in the space. The requirements of zero installation and 'automagic' proximity-based navigation posed significant technical challenges, as traditionally positioning-based systems require custom software installed as an application or app on the user devices. This challenge was overcome and the results were document as a technical research paper [200].

Bødker et al. [59] document the outcome of studying Local Area Artworks in use. The study was particularly focused on how visitors of the exhibition understood and appropriated the system, and what background experiences they used to orient themselves towards the system. We observations that when the traditionally curatorial practices were challenged through the computational alternative, it led to surprising metaphors for what people reported participating in. Some expressed that they were participating in a dialogue about the art through a stream of commentaries, while others that they participated in the artistic expression of the exhibition. We had applied a Wikipedia metaphor for the collaborative authoring on the interpretation panels in the design of the system, but this did not carry through to the visitors. The use of personal devices did provide familiarity in the interaction, and the 'automagic' navigation blended the physical and digital space together more or less seamlessly. Yet, we also observed how the panels shifted involvement and changed group dynamics from happening between people physically present together, to interaction with people who had been visiting before (or would visit in the future), and changed the pattern for how people would physically move about in the space.

City Bug Report

City Bug Report (CBR) was developed for the Media Architecture Biennale 2012 [206]. The project was collaboration between the Participatory IT centre, the city of Aarhus, Media Architecture Institute, and a local business intelligence company. The design process only lasted a few months and the design was developed at a two-day workshop involving researchers, designers, representatives from the municipality, the local open data project, the region and local companies with an interest in open data. In the project we developed two prototypes: A large media facade installation on the city hall tower of Aarhus showing an animation of four years of data on civic communication between the city departments and the citizens on a 5.500 LED display wrapped around the tower. The animation visualised incoming and outgoing communication filtered by case numbers and the visualisation was designed to illustrate how efficient the city departments responded to incoming request from the citizens. The other prototype was a web-application that allowed citizens to report issues they encountered within the city. The project borrowed the term 'bug' from software development, as a way of articulating and framing urban issues. When reporting a bug, the citizens could pick a predefined category reflecting city departments, add a description and possible solution. Once reported, the bug was added to a public list and citizens could share the issues on social media.

With this case, the municipality wanted to show their digital ambitions to the public, embrace new technologies and use civic data as a way of increasing transparency, as well as give access to and use these data to potentially change how the municipality works. From a research perspective we wanted to investigate three aspects of open data and civic participation. First, how open data and media architecture would challenge conceptions of transparency and use of civic data. Second, how open web-platforms would encourage citizens to report issues that are important to them and potentially change the way city operations identify and prioritise issues. Third, understand the process of moving public sector data from a municipal database, to an open data portal and onto a media facade and the socio-technical implications involved. The research produced three primary insights: First, getting access to and opening up data from municipal systems represent a socio-technical challenge. Not only is it difficult to give access to data deeply embedded within the municipal IT systems, the dataset in addition may contain information that, when made accessible outside the practice wherein it is normally used, exposes tacit work processes and sensitive information. Although the participants from the municipality assured us that access was a formality and that the dataset in question was already public and checked (on a field name level) for sensitive data, it was later discovered that as part of the existing internal use of the data set, caseworkers added sensitive data to free text fields. Second, at the workshop and in the initial phases, the representative from the city departments was enthusiastic regarding the potential in using citizens as a knowledge resource in identifying (and potentially solving) city issues. As the ‘bug’ reports started coming in, it became apparent to the participants that involving citizens in identifying issues came with a (legal) obligation to address the issues within a short time frame. This would short-cut the existing way the individual municipal departments prioritised maintenance and work, planned their budgets and their organisation. Inviting citizens to participate in city operations and integrating such a tool would require a major change on all organisational levels. Third, transparency works in both directions. As the project became more concrete and the actual data was shown on the media facade of the city hall tower, the participants slowly became more conscious on the potential implications of exposing the internal work processes on the highly visible outside of the building. One participant noted that the project created a sense exposure inside city hall.

CBR was the first local experiment involving citizens in identifying urban issues and the media facade was an installation developed specifically for the Media Architecture Biennale 2012. On a local level, both prototypes explored how transparency, open data and citizen participation might challenge how the municipality is organised, from an individual department level and up. The research outcomes partly inspired work on the role of urban design, participation and policy [79] and ongoing work on open data and implications related to working with data produces across contexts and practices. This would not have been possible without the fidelity of the final systems. In order to explore the taken-for-grantedness (easy access to data and citizens as a knowledge resource), it was necessary to have prototypes that would require access and allow citizens to report issues. In order to understand what transparency based on open data means, we need to make open data transparent.

CaseLine

The initial focus in CaseLine was to explore collaborative information sharing across boundaries between citizens and caseworkers using web based tools and infrastructure [63, 65]. The explicit focus on parental leave, applying for parental leave funding and the planning thereof, as it is a process that involves many potential stakeholders: Parents need to coordinate the leave plan between themselves, which in turn is affected by the parents’ respective agreements with their employers. As the leave plan potentially spans over a period of nine years, the plan for one child and its parent may overlap or collide with the leave plans of other children and previous partners. The design of the timeline tool, CaseLine, was based on insights from empirical studies of parents and municipal caseworkers and a PD process with parents and caseworkers. This design crosses the boundaries between leisure and work-life and CaseLine plays several roles on these boundaries: It is a shared planning and visualisation tool that may be used by parents and caseworkers alone or together, it serves as a contract and a sandbox, as a record and a plan, as inspiration for planning and an authoritative road, as a common information space and a fragmented exchange.

This required a different architecture than the municipal systems supports, a different way of incorporating the information already existing within the system, what is needed across stakeholders and what the individual actors provide to the system. This was reflected in how the architecture was developed and how the shared objects formed the basis for both the visualisation and the collaborative side of the prototype [see 62, fig. 1]. The design moved the thinking about the coordination of parental leave away from a series of adaptive documents [64] and records moving back and forth between the actors, to seeing it as a timeline visualisation incorporating more complex manipulation and more open, tangible plan [62]. Caseline led to a challenging discussion among the caseworkers regarding the loss of direct control over what information was given to parents. Among parents, too, parallel discussions regarding privacy and sharing over time, as well as to the possibilities of more generic sharing (e.g. on Facebook) of people's own parental plans.

CaseLine was the first of its kind in that the entire collaboration between stakeholders, not least the city officials and citizens was not mediated by technology before, if we exclude letters and telephones. The idea that one could share a plan on-line that would connect to all necessary documents, was also not described in literature, let alone the more technology-centered ideas of adaptive documents, collaboration over time, and timeline-based web-browsing. The prototypes developed were at times rough sketches leading to a more thorough high-fidelity prototype [63], prioritizing to build prototypes that were sufficing to show and users explore the ideas at various times. These prototypes served as springboards at several organizational levels in the municipal organization, both among the caseworkers, and vis-a-vis e.g. management and web-maintenance. The parents explored possibilities of the sandbox exploration among themselves, as well as notions of sharing with friends as well as with employers. Research wise this led to a new (current) focus on privacy and security.

8.6 Analysis

Despite being functioning systems deployed and running for an extended period of time, none of computational alternatives presented above provided viable, sustainable solutions to concrete problems within the respective domains. Instead, each of them illuminated challenges both technically, organizationally and in use.

Local Area Artworks demonstrated that it was doable and relatively inexpensive to enable audience participation mediated by personal devices in an art exhibition. However, it also pointed out that the facilitation of *what* visitors should participate in and *why* does not come by it self. It would require the staff (and the artists) to take an active role in the dialogue with the participating visitors. Also, that any introduction of technology, even if it is done discreetly changes the dynamics of the praxis, in this case visiting and art exhibition, significantly for good and for ill.

CaseLine demonstrated an alternative to the traditional forms and spreadsheets inspired municipal interfaces for the public, pointing to a wider set of organizational matters in the municipal organization, as well as interesting concerns regarding sharing and privacy over time, within the community of new parents, as well as across the borders to employers, friends, family and government agencies.

CBR demonstrated that it was possible to use municipal data to create a sense of transparency by visualising civic communication on the city hall tower. It also demonstrated that citizens are willing to participate and contribute by reporting urban issues. The case also indicated that transparency also creates a sense of exposure and that accommodating day-to-day citizen participation requires rethinking municipal organisation and work processes.

Each of the above cases exemplifies the use of computational alternatives as a means for socio-technical research. Each prototype embodied both technical challenges and conceptual challenges within the domain. They all worked with both high level concepts and the necessary technical steps, decisions and designs that were required to concretize the underlying design and research ideas. They all represented a number of design hypothesis, open questions related to use and research hypotheses. In Local Area Artworks we hypothesized that we could stimulate a Wikipedia-inspired collaborative writing in a local space and that personal devices as mediators for participation would create a sense of familiarity. In CaseLine we wanted to explore collaboration and the notion of shared objects and plans rather than transactional interactions around records and information. In CBR we had series of questions relating to both the installation and the web platform. Some of these were very basic: Will the data visualisation be intelligible on such a low resolution display? And, will the citizens even use the bug reporting platform? Others were more intermediate and related to the kinds of issues the citizen would report and how the city department would handle these in the future, and finally we hypothesised that concept as a whole would provoke reactions from the involved stakeholders, institutions and the public around the central concepts explore in the project.

The three cases each warrented different levels of maturity and scope required for a prototype to establish a microcosm. CaseLine addressed activities that potentially spanned years, hence a self-sustained prototype was not feasible. Instead scenarios were played with high-fidelity interactive prototype with simulated data. This of course meant that the established microcosm was not representative of a complete alternate future, but instead hinted at what such future could bring. Similarly, even though the system deployed in Local Area Artworks was self-sustained and ran without the presence of researchers, the scope was limited in that the exhibition was temporary. However, in both cases the microcosm, exposed unforeseen tensions and resistances for the specific use situation as well as for the wider potential of the computational alternative. CBR, on the other hand had an extremely simplistic visualization of data on the tower of the city hall, so simplistic that it was more or less unintelligible by the passers-by on the street, but as a microcosm, it required substantial extra work getting this established with the specific dataset and the media facade in particular. Yet, the established microcosm of an alternative future where municipal data is exposed so prominently pushing internal conceptions of transparency, puncturing or stirred the municipal hornet's nest in a way we believe would be difficult to have achieved without making it real and concrete.

CaseLine and CBR both tapped into municipal systems and workflows, by changing how we use and represent data, in the interface as well as in the architecture. CaseLine moved more isolated bits and pieces of information (records) up into a shared information space, and CBR pushed data from within the depths of a municipal database into a visualisation displayed on the huge low-resolution media facade enclosing the city hall tower. Similarly, they both played with changing ownership and the right to define aspects of municipal case flow, either by providing citizens with a platform that potentially turns the process of identifying and prioritizing important city issues inside out, or in CaseLine by combining information from multiple sources and allow parents to experiment with and change the elements of the parental leave more fluent and continuously. Local Area Artwork played with renegotiating who can and should curate and produce the text describing the artworks in the space of an art exhibition. Again, ownership over parts of the institutional information space was delegated to the visitors in an attempt change how we participate and engage with an art exhibition. As with the other cases, this required both tailor-made infrastructure and/or architecture, utilization of (web) technology, and for Local Area Artwork, the development of a zero-install proximity system to make this new relationship between the viewer (now potentially writer) and the art works a spatial one on the technical side as well. As such, each case is a computational alternative, as they both attempted to explore and tackle socio-technical challenges, while focusing on the reciprocal relationship between both the concrete praxis and the technology.

LAA and CaseLine both demonstrated how the praxis of use encouraged critical development of technology. In LAA a technique was devised to allow participation using personal devices without requiring a lengthy app installation, while also allowing for WiFi proximity detection to simplify navigation and only allow the editing of texts when in close proximity of an artwork. In CaseLine the challenges of collaborating around planning over long time spans, challenged the traditional document centric model of the web, resulting in the development of novel timeline based interaction for the web. Local Area Artwork also played with very mundane concepts partly introduced by how we think web technology and networks, questioning if the taken for granted global access is always an ideal or participation could be a matter of being situated or proximate. This renegotiation of rights based on infrastructure also prompted a negotiation of who writes the texts in the space of an art exhibition and created a tensions related to ownership and roles. Similarly, CBR and CaseLine created multiple tensions on ownership over public records, information flow and division of work. Who is the planner, when we move from documents to a collaborative timeline or delegate the right to define urban issues and matters of concern to citizens?

8.7 Discussion

With the notion of computational alternatives we point to the need for and potential in reinvigorating a socio-technical research agenda within PD wherein technology development play a central role. When reviewing the technological contribution from the early PD projects, we see that strong PD research can contribute to the development of programming languages, models, graphical interface design, work-flow systems, hypermedia models etc. The same work give some indications to what is to be done if PD research have ambitions of making similar contributions. Common for the work is a) having the focus on socio-*technical alternatives* as part of the initial research agenda [45, 159], b) engaging in technology production as part of the collaboration with stakeholders [45, 119, 263], c) having the technical insight to identify, formulate and propose 'deep' technical implications and shortcomings in contemporary models [99, 152]. This does not imply abandoning understanding the process of technology development or the existing positions in PD, rather, to recognise the value in and necessity of developing computational systems as part of furthering those research perspectives as well. The researchers in the Florence project outline this relationship in a simple way: *"Knowledge of system development was the overall goal of the research project, more important than any products or computer systems. However, it was necessary to develop a computer system in order to create a setting of cooperation with the nurses."* [45, p.167].

We find the alternative, to *not* engage in technology development in PD research, problematic. As Kyng [220] rightly points out, the final system (or design and research insights from the PD process) will be implemented on a computer in some form or another, at least if we still claim that PD is an important position in designing computational artifacts. This means that computers should be a part of the process and that it is important to show how to move beyond early analysis and methodological concerns [260, 286]. Not questioning existing technologies, either in the process or by proposing computational alternatives, could be interpreted either as an instrumental position toward technology and/or as an insensitivity to the representations of work, collaboration, participation, sharing, community etc. already embedded contemporary technologies (from devices, over operating systems, to applications). Do contemporary technologies adequately represent work? Not having the above in mind or never moving beyond the early phases might also indicate that the outcome is insignificant and all is about the community work and feel good processes [14, 357]. Is it?

8.8 Conclusion

Through an examination of early PD research projects we show that Scandinavian PD is defined by how it balanced socio-technical alternatives. We have argued that a strong technical commitment has faded in PD, and propose computational alternatives as a perspective to return to and maintain a technology research agenda from within the PD tradition. This is based on recent discussions in PD and related fields on the lacking technology focus in PD research, and through analysis and discussion of three recent cases.

8.9 Acknowledgements

We would like to thank the reviewers for insightful comments throughout the review process. This work is funded by the interdisciplinary Participatory IT centre.

Chapter 9

Publication II: 'A Farmer, a Place and at least 20 Members': The Development of Artifact Ecologies in Volunteer-based Communities

‘A Farmer, a Place and at least 20 Members’ The Development of Artifact Ecologies in Volunteer-based Communities

Susanne Bødker, Henrik Korsgaard and Joanna Saad-Sulonen

Abstract

In this paper, we present a case study of an urban organic food community and examine the way the community shapes its artifact ecology through a combination of appropriation of freely or cheaply available tools, and the long-term effort of building the community’s own website. Based on participatory observation, content analysis of communication documents, and a series of interviews, we see how the collection of artifacts that a community uses to support their practice form what we refer to as their *community artifact ecology.* A community artifact ecology is multifaceted, dynamic and pending on what the members bring to the table, as well as on particular situations of use. The community artifact ecology concept is important for CSCW as it enables framing of the relationship between communities and technologies beyond the single artifact and beyond a static view of a dedicated technology.

9.1 Introduction

In this paper, we present a case study of a local organic food community, their struggle and creativity in finding and appropriating specific computational artifacts, software applications and devices alike, to support their developing practices. Through participatory observation, content analysis of communication documents, and a series of interviews, we trace the history of the community from being a few selected people searching for a potential for action around a matter of concern, to a growing and established community with practical concerns and duties to fulfill. The entry point to this is a study of the genealogy of the community and its artifact ecology: The collection of tools that the community uses to support their core activities, which are based on voluntary work. Like many other self-organized communities, based on volunteering work, this one operates with little resources and with an open and fluent way of organizing their work. The aim of the paper is to bring forward the kind of everyday ‘vernacular’ design work (e.g. [166]) that volunteer-based communities engage in, to shape a working artifact ecology that supports their needs. This enables us to better pinpoint potential areas of CSCW research with volunteer-based communities, especially in the contemporary context where there is an abundance of tools available. The questions we seek to answer are the following:

- What constitutes an artifact ecology in the context of volunteer-based communities?
- How do such communities shape their artifact ecology?
- What role does the artifact ecology play in the shaping and the development of the community?

In the following, we argue that establishing a community artifact ecology is an inherent part of shaping the community and plays an important role in the formation and ongoing life of a community. It shapes the community as much as other elements, e.g. manifestos, regulation, membership terms and the community space. To understand how self-organized communities go about their work, it is necessary to consider how they establish, provision and work with their community artifact ecology. By addressing the development of volunteer communities through the perspective of community artifact ecologies, we aim to focus on the technological mechanisms that support, develop or hinder the emergent practices and purposes of the community. In contrast to previous contributions in this area, the importance of this contribution lies in drawing attention to the multiplicity of experiences and technologies that are brought into play in such a setting.

9.2 Background and Related Work

Whereas CSCW has always discussed work as an activity that goes beyond paid labor [57], this has not happened without discussion [see 22, 313]. Lately, there has been a growing interest in the notion of voluntary work as a type of collaborative endeavor. These endeavors can be temporary (e.g. as responses to disasters [see 356]), they can happen through everyday help-giving [e.g. 343], or as longer-term activities that eventually scaffold the shaping and sustaining of communities around particular concerns [e.g. 132]. Community is a wide concept, which is also applied outside work settings: In CSCW, attention has been to online communities and community networking systems [e.g. 84, 264, 289]. Preece & Maloney-Krichmar [289] summarize this research and look at how communication and interaction among members of online communities may be supported, whether at work or not. In many parts of the world, alternative models for the production and distribution of food are being explored. In agriculture and food studies, these are referred to as civic food networks [297], or Alternative Food Networks (AFN), as a representation of the so-called "quality turn" that emerged as a reaction to disappointments in mainstream industrial food circuits [144]. In practice, this means that, triggered by concerns over food safety and health, economic strain, ecological ideals, and/or civic activism, there is a portion of the population in various locations worldwide that is putting effort in getting access to clean, local, and often organic food. This has prompted new alliances between cities and the countryside by reconfiguring the distribution chain and creating direct links between city dwellers and farmers [241], and an interest in e.g. urban gardening communities [235, 346].

The theme of sustainable food has been picked up by [e.g. 92], and is situated in the wider discussion on sustainability [105]. Food distribution networks have been discussed by [132], communities of organic farmers by [228], and urban gardening communities by [11, 235, 324, 346]. In the wider field of organizing and collaboration online, recent studies of time banks [37], crowd-funding [182], online learning communities [262] and other forms of sharing communities are equally relevant [240]. However, much of the discussion remains focused either on the use of existing digital tools or online platforms to support these activities, or on the design of new ones, often from a monolithic perspective. Additionally, in the recent CSCW cases, the use of multiple technologies is studied inside a multiple user setting of relatively short-lived situations [142], or of established online enterprise communities [248]. Despite its main focus on communities of practice at work, CSCW has nonetheless provided a number of perspectives that are useful for the current case: Communities, as researched in CSCW, have often been defined with a background in Lave & Wenger's [223] definition of communities of practice, which means a focus on learning, as a journey for newcomers into central members of the community, and the roles of routines, the physical setting and artifacts, often, but not entirely, within work. Other parallel theoretical framings have included socio-cultural activity systems, or a combination of the two within work settings and beyond [65, 77], emphasizing also that communities 'work' whether this is as paid labor or not.

CSCW has been focused on how groups pick, orchestrate, use and work with multiple software systems over time, e.g. Pipek & Wulf [287], Star & Ruhleder [321], and strategies to cope with systems that do not smoothly support collaboration routines [67]. Upon these roots, several authors use Star & Ruhleder's idea of infrastructure and infrastructuring to embrace the notion, that technologies are appropriated and reappropriated into networks of technological infrastructures and use situations, not only within paid work, but in wider purposeful activities [195, 287].

9.3 Theoretical Framing: Artifact Ecologies

In the aftermath of ubicomp (see e.g. [49]) it has become evident that technologies do not exist in isolation from each other, and should not be understood and built as such [28, 40, 55, 191, 214, 279, 307, 320, 333]. In continuation of the work by Krippendorff [214], Jung et al. [191], and Bødker & Klokmose [55], we use the terms *artifact ecologies* to focus on the ways in which human beings, as individuals or together as groups or communities, are surrounded by multiple technologies, applications and devices alike, that they appropriate and use in different combinations for shifting purposes over time. Jung et al. refer to an artifact ecology as *"a set of all physical artifacts with some level of interactivity enabled by digital technology that a person owns, has access to, and uses."* [191, p.201]. In their work, the composition of the artifact ecology is closely tied to the personal context and purpose of use, as well as to how the artifacts are connected through functional compatibilities. Based on their study, the authors conclude that *"Ecologies evolve according to individual users' personal strategies and appropriation of artifacts."* [191, p.209]. New artifacts have the potential to both influence new use patterns and the way in which the existing artifacts are conceived.

However, an artifact is not only a physical device. Krippendorff [214] argues that we cannot distinguish between software, hardware and individual devices when it comes to computing. Bødker & Klokmose [54, 55] similarly focus on the mediation of use, by software as well as hardware. They expand Jung et al.'s definition of the artifact ecology by pinpointing its *collaborative and dynamic* nature: It unfolds around the introduction of new artifacts and moves through different states in a dynamic relationship with other artifacts, people and their activities and practices. In the *unsatisfactory state*, the ecology no longer lives up the needs or expectations of its user. When a new artifact is added to the ecology, the ecology goes through an *excited state* where the new and existing artifacts are explored and (re-) assessed. In the *stable state* the artifacts have found their role and the ecology at large functions in everyday activities. Changing configurations of people and activities are hence dynamically related to changing configurations of artifacts [47, 54]. In this dynamic whole, past artifacts as well as future ones may play a role for the shaping of human practices, and accordingly they may be usefully considered part of the artifact ecology. This historical view also fits well with Ackerman et al.'s [3] definition of *resources*, based on a summary of analyses of a number of physical and virtual artifacts for coordination and collaboration in a variety of communities of practice: *"A resource is an entity that is used in a particular manner to address a recurring need or problem. Its manner of use is characterized by shared expectations, understandings and practices that have built up during the history of its use in a specific environment."* [3, p.310]

The work of Nardi & O'Day [268] and Bell [35] emphasize localities as an anchoring point for place-specific ecologies, such as the museum or the library. Nardi & O'Day's information ecology or Bell's cultural ecology addresses places where people take part in activities related to a specific domain and interact with the artifacts available in this local environment. Nardi & O'Day point out that a healthy ecology is always in motion, and describe how *"[P]eople's activities and tools adjust and are adjusted in relation to each other, always attempting and never quite achieving a perfect fit."* [268, p.53], while still displaying *"stable participation of an interconnecting group of people and their tools and practices."* [268, p.53]

Rossitto et al. [307] introduce the concept of *constellations of technologies* to refer to the several technological artifacts and applications that people use as part of cooperative work. Based on their study on how students negotiate and orchestrate artifacts and applications in their nomadic group work, they discuss how constellations are made in use, and the process of making the constellation work. They argue that a constellation is unique to a particular group and that individuals can use different applications within different groups. The performative process of appropriating these artifacts (*aligning constellations*), happen in the interplay between the situation at hand (place, time and activity) and in negotiation between *proposers* and potential *adopters* within the group. A particular constellation of a group emerges from the intersection of the multiple artifact ecologies of the individual group members. Rossitto et al. describe how some of the artifacts are sometimes negotiated in the beginning of a project, while emergent needs (cf. an unsatisfactory state) can result in the introduction of a new artifact. An individual might act as a proposer (the more capable peer in Bødker & Klokmose's [55] activity theoretical vocabulary) and suggest a potential artifact to the group – which then again might create tension (cf. unsatisfactory state and excited state) in the intersection between the ecologies and personal preferences of the participating members.

To summarize, we have expanded the original concept of artifact ecologies to include a community aspect and we have taken it to a new social setting, that of volunteer-based community work. We see a community artifact ecology as the particular constellation of artifacts that a community owns, has access to and uses in its activities. It is characterized by a high degree of shared understanding of the core activities and the role of the artifacts within the ecology. The community artifact ecology emerges from the combination of the different artifacts that key members introduce from their own personal ecology. It changes throughout the community lifetime in response to community needs. This occurs both through explicit negotiation and more subtle adoption of artifacts originating from the ecology of individual members, often more capable peers. It is both dynamic, as it co-evolves with the community, and stable beyond the individual member. While particular artifacts may stem from individual members, they are often adopted by the community and become part of the community practices and shared history. After presenting our research approach, we will look at how a particular community, based on volunteer work, shapes its artifact ecology and how this ecology co-evolves with the community itself. We examine the different stages the community and its artifact ecology go through, and the circumstances, tensions and work involved in establishing and maintaining the community artifact ecology.

9.4 Research Approach

In some of our previous work with volunteer-based communities [180], we began examining the different tools such communities use. In order to better understand why and how communities organize and work with multiple artifacts as part of their practices, we now sought to study in depth a local organic food community in Aarhus, Denmark. We have first approached the community when one of the authors became a member and started taking part in community activities. Based on the initial insight and a review of the community website and Facebook page, we began formulating our research goals and tentative research questions. In order to understand what were the tools used by the community and how the community actually developed the suite of digital tools and aids that support the community activities, we first started with participant observations during community activities and a series of interviews with core members. After trust was gained, we got permission to go through the recorded minutes from community meetings throughout its lifetime and reviewed them. The interviewees were recruited based on their knowledge of the community and long-time membership in the community and the core organization. The interviewees are between the age of 25 and 45 and all have been long-time members of and/or played a vital role in the formation of the community and development of the community artifact ecology, see table 9.1. This include a founding members, the current developer of the website, participants from core work groups (communications, shop, products and ordering), and a board member, who is responsible for the contact with authorities. Four of the participants have been members of the board and played leading roles in core work groups.

We chose a semi-structured interview format and followed a base guide in all the interviews. The interview touched upon the respondents' introduction to the community, their characterization of the community and community space, technology and activities, and current challenges. The guide was amended between the interviews to accommodate different roles, (see the 'roles' column in table 9.1). Two of the interviewees were interviewed together[1], and we conducted one follow-up interview for clarification and elaboration with one participant[2]. The names of the respondents have been changed for this publication. Inspired by Jung et al. [191] and Cabrera et al.[80], we experimented with mapped events, artifacts and people on a timeline together with two of the participants[3], in an attempt to capture the chronology and key elements to aid us in our analysis of the interview data (see figure 9.1). We used the mapping exercise with one of the founders to establish the overarching chronology of the community and with the current developer in an attempt to map the development of the website.

The primary data in the study is the transcribed interview data. In addition, we have also used our observation notes from 8 hours of participant observation, conducted during packaging shifts at the community space at four occasions, as well as minutes

Name	**Role(s)**	**Membership**	**Interview length**
Laura[3]	Founder, work group & board member	2010 – 2014	01:07:05
Karen[1]	Work group & board member	2012 – now	01:09:48
Nadia[1,2]	Work group & board member	2011 – now	00:48:31 (01:09:48 follow up)
Robert	Work group and board member contact to authorities	2011 – now	00:54:48
Paul[3]	Work group member & web developer	2011 (active 2012) – now	01:02:19

Table 9.1: Interviews and respondents role within the community.

from the community meetings (open assemblies and working group meetings) from the last four years (N=153), which are available in the members-only section of the website (we were given permission to access them and analyze them by the board members at a later stage). The two maps from the interview sessions were used as supplementing material throughout our internal analysis and to identify key artifacts in the ecology.

Our analysis has focused on three aspects in the data, namely establishing the elements of the ecology, its chronology and how it developed, and examining the interplay between the community activities and the ecology. The data was analysed in two steps. First, we coded the transcriptions individually using open codes to identify common themes, *artifact, introduction, change, collaboration, breakdown, software, challenges, activity, need, community* etc., and then consolidated these through comparison across the interviews. Second, we used the themes to further identify central statements in the interviews and compared these through meaning condensation (see [219]). The themes and focus are presented in the analysis below.

Study limitations

Acknowledging the limitations of a single case study, we find Flyvbjerg's [128] argument for the relevance of good case narratives valid in our case, which is further triangulated with theoretical insights regarding artifact ecologies. He introduces the idea of paradigmatic cases, *"cases that highlight more general characteristics of the societies in question"* [128, p.232] and allows researchers to develop a metaphor or a new school of thought. Our study allows us to explore and examine how self-organized communities use and orchestrate multiple artifacts as part of their practice. This in turn aids us in further developing the existing theoretical conceptions of artifact ecologies. The findings presented here are particular to the specific case and cannot be generalised to any community. We use the particular findings to start theorising on the dynamics of artifact ecologies beyond the individual and how communities orchestrate their particular

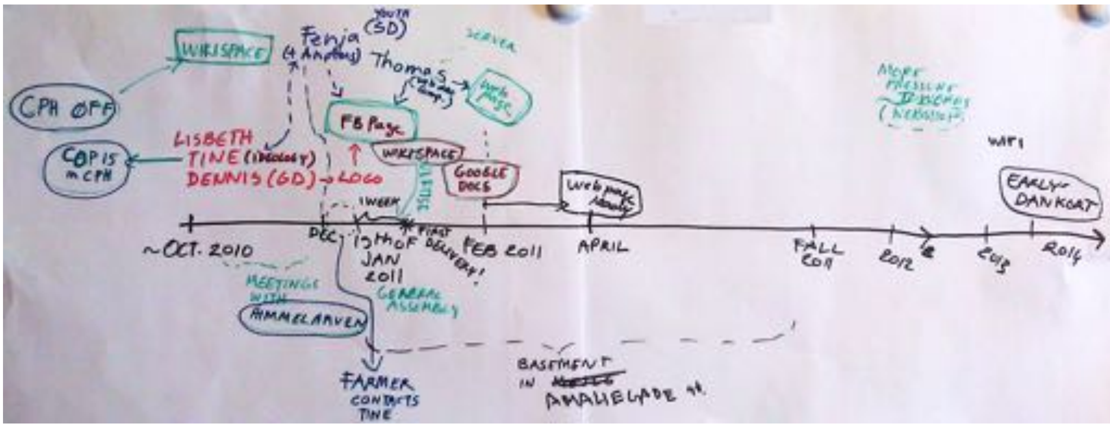

Figure 9.1: Overview map from interview with Laura

artifact ecology. We will return to the limitations in the study in the discussion.

9.5 Case Study: The Organic Food Community

The reported research is based on a case study of an organic food community in Aarhus, Denmark, a city with a population of around 300.000. The city is a university city with a large percentage of younger people. This is also reflected in the member composition of the community. The community was started in late 2010 by two women wanting to find a cheaper and more sustainable alternative way to get fresh local organic food, inspired by initiatives that were sprouting worldwide. Both had worked with organic food production and sustainability as part of their university studies. The community has grown at high rate and has now around 900 registered members (and around 3000 likes on their Facebook page). According to their own website (AOFF.dk), their mission is to offer cheap, local organic fruits and vegetables, and through that spread information and awareness on organic and sustainable food production in order to engage members and locals in sustainable initiatives. Their manifesto and founding principles reflect their core values, which relate to a strong ideological stance on local organic and sustainable food production, collaboration and community, knowledge sharing, and emphasizing a high degree of transparency within the community organization and in the distribution channel.

> *"Organic for all! The Aarhus Organic Food community is a member-owned and operated cooperative food community - an alternative to ordinary profit-oriented supermarket chains. We offer organic, tasty, locally produced and sustainable food in season for the lowest possible price. We offer a great selection of organic vegetables and fruits, and support sustainable farming.[…] We want to set an example by educating ourselves and others about food and health, collaboration and the environment."*
> (Excerpt from the manifesto published on the community website, translated to English by the authors)

While the community identifies as a 'fællesskab' (literal: community), creating a 'forening' (literal: association) is the most common way to create a formal organization in the local context. An association is a particular Danish organization form and legal entity that provides some benefits, e.g. financial support and use of public facilities, while also requiring a board, by-laws and a yearly general assembly. The organic food community is highly organized with a board and seven working groups covering the tasks involved in managing the community, arranging events, coordinating with authorities (permits and hygiene inspection), buying and coordinating with the local farmers, and selling and distributing the organic food goods to the ordinary members of the community. The board and the working group represent a stable core group of members of approximately 40 volunteers. According to the website and our interviews, the community organization has a flat hierarchy and is open to all members, with weekly meetings in the working groups, monthly community meetings and an annual general assembly, where the board is elected. However, it is clear that the members involved in the board and in the working groups constitute a sub-group of particularly active individuals. Other members are nonetheless expected to participate in the Thursday afternoon activities and actively encouraged to join the monthly community meetings via the community newsletter and the Facebook page. Members pay a fee upon joining the community and they are required to volunteer with three hours of work each month, coordinated through a scheduling tool on the community website.

Community space and Thursday activities

The primary activity of the organic food community is the distribution of the weekly bags of locally grown organic food to the community members. Each Thursday, local farmers deliver the pre-ordered food goods outside the 'residents house' – a shared local community space close to the city center, after which volunteers work to pack and hand-out the bags to the community members stopping by to pickup their order. A typical Thursday starts around 12.30 at the community space, where the members, who signed up for the packaging shift, meet and start packaging. The first tasks are to unpack the packaging gear (bags, bowls, weights, gloves etc.), turn on the refrigerator and put out the food-handling manuals and authority reports which need to be visible to everyone as part of the requirements for food-handling (in case of unannounced inspections by the authorities). When the farmer(s) arrive, everyone helps unloading and starts weighing and packing the goods into individual bags for members to pickup. Written manuals (also available via the community website) contain detailed instructions on how to setup and do the packaging efficiently. After the packing is done, they clean the room thoroughly and setup the community laptop and credit card terminal so that it is ready for the next group. Packing usually takes three hours and around 3.45 pm, two members of the selling shift take over, handing out bags and taking orders for the following week. Around 5.15 pm the second shift starts and the two members handling the shop are replaced. The community manuals contain detailed information on how to setup the shop, keeping track on orders and payments, use the credit card terminal and spatially organize the bags, tables, order and payment area, etc. The shop is open for community members from 4 pm until 6.30 pm. When the shop closes, the late shift members pack, clean and close down the community space. A typical Thursday ends around 7 pm.

Each week, members place orders for the following week and based on the number of orders, members of the responsible working group contact the local farmers to see what food goods are available, and order the needed amount. The incoming orders from the members and the orders that go to the farmers are currently collected and maintained in several different Google spreadsheets. The contents of the bag for the following week is the posted on the community website and Facebook page, often together with recipe's collected by the recipe's group. The bag of food goods is sold at a fixed price, which has gone unchanged throughout the community lifespan. While there is a seasonal list on the website, and the contents of the weekly bag is announced as soon as possible, the members do not know exactly what is in the weekly bag until the details are announced. From our observations and interviews we see how sharing a space on Thursday afternoons plays an important, yet subtle, role in the way the community shapes itself. Having a place to distribute the weekly bags of vegetables is a defining trait of the community and an integral part of its activities.

> *"So, as we grew and got a bit more established, we also needed to [move]. But we also really wanted to have own space where we could make it a little bit cozy."* (Laura)

When asked, the interviewees emphasized the face-to-face meeting, personal relationships and community activities as the situations, where the community best comes to life:

> *"Well, it happens on Thursdays, it happens in person. [...] We have a lot of followers on Facebook and we post various things there, but I think everything community-wise kind of happens in person, either like in the opening hours or at the meetings."* (Karen)
>
> *"The community feeling is when I am actually at the shop on Thursdays and when we have a meeting. And you see people face-to-face. I don't feel that we have a very strong community on Facebook or anywhere else, virtually. It is more the personal relationship I have with other members when we see each other."* (Robert)

The relationship to the community space is not only functional, even though the residents' house is a shared space. It is part of the community identity and having some say over how it is organized during the shifts on Thursdays is important to the community members. The interviewees identify the community with the activities happening every Thursday. The website plays the role of closely supporting these activities, e.g. manning shifts, information on handling food goods, and through the focus of the working groups. It is only possible to become a member by visiting the community on Thursdays. This is not by deliberate decision, but rather a result of a member registration feature never being implemented on the website.

9.6 COMMUNITY WORK AND THE ARTIFACT ECOLOGY

In the following section we analyze how the community and its artifact ecology develop hand-in-hand. By studying the practices of the community in question, its purposes, tools, and places, we have identified three main conceptual stages in the formation and establishment of the community and its artifact ecology: Becoming a community, everyday community work, and building anew. These stages are characterized by some (temporary) stability in terms of foci, concerns, artifact, and activities, which are grounded in the empirical study. The stages are used descriptively and conceptually, and should not be read as prescriptive, a point we will return to in the discussion.

Becoming a community and first steps in shaping the ecology

The two founders of the community were interested in finding cheap and responsible models for getting local and seasonal organic food. One of the women had heard of the Copenhagen organic food community while talking to people at the UN Climate Conference (COP15) that was held in Copenhagen in 2009 and subsequently invited a representative from Copenhagen over to learn more about how to start a local organic food community in their city. At that meeting he presented the basic requirements for starting a community similar to the one in Copenhagen:

> *"You need to have a farmer, you need to have around 20 members, so you can at least order 20 bags, because otherwise the farmer is not gonna be able to deliver for you. [...] And then we needed a place and some bags to put the vegetables in."* (Laura)

They followed the advice and started a local initiative based on the model from Copenhagen, which is an association model; build around multiple working groups, volunteer work and a community wiki as the primary organizational platform. One night late in October 2010, the two founders, created a logo (with the help of a graphic designer) and a Facebook page to put, as one of interviewees said, *something into the world* and see if there were similar initiatives and/or like-minded people in their local area. The Facebook page proved to be a very efficient way of triggering interest in the ideas of sustainability and in the ambitions to develop a local alternative to the existing ways of buying local organic food. Facebook played a vital role in the initial formation of the community. Within weeks the founders were approached by a web developer, who offered to develop a free website for the initiative, a representative from a local youth wing of a political party, who offered the community a meeting place, and a local farmer, who wanted to supply organic vegetables to the community. According to our interviews, they had all seen the initiative through the Facebook page and offered their help and services, because they sympathized with the initiative and shared parts of the ideas related to organic food and sustainability.

> *"[...] there are so many different types of communities and the visual impression that you give out is quite important to the target group who can feel like, they can identify us"* (Laura)

The community officially became a registered association after the first general assembly in January 2011 and active members started to take orders and distribute weekly bags of organic food to the then approximate 30 members. Initially, the community adopted the concept, organization, regulations, and the use of a community wiki (Wikispaces.com) from the initiative in Copenhagen. At the first general assembly, the founders presented the organization, comprised of a board and a series of working groups, the founding principles and manifesto, which emphasized a flat, consensus-based organizational structure aa well as the aim to provide cheap organic food. The ambition was not just to create an association that would offer cheap organic food (as a service), but as one of the founding members put it:

> *"The idea of the association was also to create a community, like a sense of we have something in common and share the ideas of organic production."* (Laura)

While the community at first adopted the use of a wiki from the established community in Copenhagen, and found it somewhat useful in the beginning, they quickly started to see problems in using this as a community platform. The issues were both related to the functions and how the wiki reflected the community identity and values. The founders wanted a community platform that was easy identifiable, reflected the community (i.e. sustainability and being well-organized) values and incorporated a more professional image (opposed to other grassroots organizations as one interviewee put it). A more functional concern was related to the openness of the wiki format and the platform was assessed less user-friendly than other tools.

> *"We also initiated a Wikispace, but we saw that the problem with Wikispaces was that everything is public. They [the Copenhagen community] would put their schemes for when people are working and have [their] emails and contact information [public]. We saw that was a problem and this is why we wanted to create our own homepage, where you login and then you can see the shifts. Yes, and I also wanted to make it more user-friendly, because I didn't think Wikispaces was so user-friendly."* (Laura)

The issues with the wiki and the opportunity to have a custom-made website motivated the community founders to develop a wish list for the new website, e.g. a members' section, shift management, working group section, repository for community documents, dedicated emails aliases, newsletters and later online ordering and payment, essentially creating an informal requirement list for the web developer, who volunteered to develop a new website for the community. As a way of handling part of the transition to the new website, a founding members introduced the use of Google Drive to handle some of the tasks like managing lists in spreadsheets for ordering bags and deciding on the content of the bags based on available food goods from the farmer. Google Drive was introduced mainly as a collaborative tool to coordinate internally among the working groups, and was based on previous experiences by the founding members:

> *"That was me who brought the idea about Google Drive [...] because I had used it for something else. Then I saw the potential of, it's a good... because it was better than Dropbox, because Dropbox has some problems when you, when there are several users working on the same document. Whereas Google*

Artifact	Origin / Inspiration	Primary Role
Facebook page	Founding members	External and internal communication Visibility and recruitment
Wikispaces	Copenhagen community	Internal and public information Internal organization and management Initial community platform
Website (v.1)	Founding member and volunteering web developer	Substitute Wikispaces as the primary community platform
Google Drive	Founding members	Substitute the collaborative and elements in Wikispaces and supplement the website
Community mail (aliases)	Founding member, managed by web developer	Substitute Facebook for internal communication and contact

Table 9.2: The community artifact ecology in the first stage.

> *Drive is working better in that sense. And we needed something that was more user-friendly. It synchronizes all the time, even though there are several users editing the same document at the same time."* (Laura)

At first, the community artifact ecology was strongly influenced by the model adopted from Copenhagen and included elements introduced by the founding members. However, the emergent functional and stated preference for a site that reflected the community values in a more consistent and professional way, and the opportunity to get a community website (for free) resulted in an early abandonment of the wiki as the primary community platform. The community website was launched in the spring of 2011. The community manifesto was published there along with other practical information regarding the community. The core 'trinity' comprising of a Facebook page, various Google Drive applications, and the community website, was established very early in the community lifespan (around October 2010 to February 2011), in relatively short time, with few resources and by a very selected group of people. We have summarized the collection of artifacts in the table 9.2, as it looked in the formative stage of the community.

Everyday community work, needs and workarounds

From early 2011 and onward, the core of the community work took place around managing the community and the weekly work of ordering, packing and selling the vegetables. The process of getting volunteers for the individual working groups, manning the shifts, composing the weekly bag and introducing new organic products was the main focus. Although the website was launched in the spring of 2011, many features were not implemented yet. This created frustrations as well as gaps that had to be filled, in order to keep up the community and management work. Some of these frustrations were due to the slow pace of the website development or the way the website was designed. The slow pace, in turn, was also due to the volunteer developer's choice to no longer be active in the community. For instance, communication among the working groups, which had been set up through a mailing system associated with the website, had to be bypassed eventually and some of the working groups resorted to a workaround:

> *"[...] through the website, we have some [the organization domain name] emails, and we can't get access those unless we get the code from him [the web developer/volunteer], and he is impossible to reach [...] I ended up making a Gmail account for [one of the work groups], because I simply couldn't get the account transferred."* (Karen)

Thus, some of the groups deviated from the initial ambition to have specific community email addresses for the core members. Later, the group responsible for communication would formulate a communication strategy in order to separate the communication to the public from information suitable only to members. They adopted an external email service to handle newsletters and information for the members, while keeping the Facebook page for more open and external communication. The communications group added a Twitter and Instagram account to supplement Facebook. There are also other examples of the creative ways in which the community dealt with the difficulty of accessing the community website. The volunteer developer had chosen a CMS that he was familiar with, and this created problems with access to maintenance of website, once he withdrew. Another community member volunteered to take over, but without proper access to the original website back-end, he had to resort to a technical workaround in order to get e.g. a basic community calendar working:

> *"On the front [of the website], there's a [Google] calendar. That is made through a hack, because I've got access to the database, so I made a hack, where I went into the database and put in an iframe as a content element [...] so that's not done through the CMS at all [...] [I] injected some SQL into the database, which [enables] the calendar feature."* (Paul)

As the community grew, it needed better facilities for packaging and distributing, as well as a more established community space that would support the Thursday activities and a stronger sense of community. To help the increasingly complex task of taking orders, handling payment and managing the distribution of the organic food each Thursday, the community members discussed getting a community laptop that could be used to keep track of the orders in the multiple Google spreadsheets. This was discussed at meetings throughout 2012 and around December 2012 a community member (Nadia) donated an old laptop. Besides being used to manage the orders to some extent, the laptop is mainly used to lookup member information and connecting a credit-card terminal to the Internet via the community WiFi hotspot. The introduction of the credit card terminal stems from early discussions at community meetings on having an online ordering and payment system, something that were on the wish list for the first website, as far back as early 2011. The credit-card terminal was originally envisioned to be a backup for the online payment system and was acquired together with license for having

Artifact	Origin / Inspiration	Primary Role
Facebook page	Founding members	External communication
Twitter	Communications group	External communication
Instagram	Communications group	External communication
Wikispace	Copenhagen community	Used by a few work groups for minutes and information up until September 2014
Website (v.2)	Founding member and volunteering web developer	Primary community platform, news and events, managing shifts, community documents
Google Drive	Founding members	Supporting the work related to Thursday activities
Google Mail	Communications group	Substitute the community email alias'
MailChimp	Communications group	Newsletter service for internal communication to all members
Community Laptop	Donated by member	Used to access Google documents and community information each Thursday
Community WiFi	Bought November 2015	Used to access online services with laptop and credit-card terminal
Credit-card terminal	Communications group	Credit card payment in the community space
Ad-hoc artifacts used by members	Members	Supplement community laptop Alternative WiFi when community WiFi is down

Table 9.3: The community artifact ecology in the second stage.

an online payment system. This was initiated around July 2011 and the credit-card terminal was finally functional around June 2014, and, as the online payment system has not yet been implemented on the website, the credit-card terminal is for now at least a stable artifact in the community space (it might be abandoned if the online system is eventually realised).

Through participatory observations one Thursday we saw examples of situated workarounds: The WiFi provided by the residents' house was down. There, spontaneously, one of the community members, responsible for payments, shared his own mobile Internet connection and connected the shared credit card terminal to his own laptop, so that people could pay by card. Similar acts of sharing one's mobile Internet connection and/or sharing one's laptop were also reported in the interviews. While many of the artifacts introduced early in the community lifespan still remain a part of the community artifact ecology, they have undergone changes in the roles they played, as new artifacts were introduced. The changes and introduction of new artifacts appear to be a response to the change in focus of the community activities as well as a means to overcome frustration with existing tools. While the establishment of the community, their practices and initial ecology was the focus in the beginning, the growth of the community and stronger focus on supporting the Thursday activities, is reflected in the community artifact ecology. In table 9.3, we have summaries the community artifact ecology as it is in the stage focusing on the core community activities.

Growing pains and building anew

The design and development of the first community website had begun in late 2010 and an initial version was up during Spring 2011. In June 2011 the member section with login was introduced and in November of the same year the component to handle shift reservations. However, the website and its functionality continued to be a recurring topic at community meetings. Needs for new functionalities kept arising (e.g. a possible online payment system and an online signing up possibility for new members), and frustrations with existing ones were expressed (e.g. the inability to establish both an easy way of communicating to all members via email and assign email addresses to the work groups). As the community grew, the burden of management increased and at the end of 2013 the situation with the website and the general management of the community had resulted in frustrations within the community work groups:

> *"Well, every week there are some practical problems that we have to solve. It's just, it's not fun. And this is supposed to be fun, this is supposed to be something [where] you put in your work because you want to do it and you feel like you get something back. And for a long time people have just been tired from doing all the various tasks."* (Robert)

Getting the new website became an important priority for the community throughout 2013 and 2014 and the decision to build a new website was discussed and agreed upon at an open community meeting late 2013. A decision was taken that the community, as a legal association, would pay for one of their members to develop the new website. Despite this being against their principles, this was decided. The new developer (Paul) was a long time member of the community; an IT professional who had regularly stepped in to solve technical issues. Shortly after discontinuing the collaboration with the first web developer, the new developer prioritized the features for the new website and started developing it using a new CMS, which he was accustomed to use in his professional work. To the new web developer, the task seems straightforward and as a community member, he gave the impression that he knew what is needed and what was most important. He had also invited other members to take part in the work by using an online project management system, first as a more participatory endeavor, and later as a way to assign tasks:

> *"It's gonna be a waterfall model running because, there's no time for [...] you know the agile stage is over."* (Paul)

All our interviewees regard the new future website as the long-awaited solution to many of their current problems. For example, it would solve one of main struggles of the community, namely to get enough volunteers to take part in the Thursday shifts.

Artifact	Origin / Inspiration	Primary Role
Facebook page	Founding members	External communication
Twitter	Communications group	External communication
Instagram	Communications group	External communication
Website (v.3)	Community work groups, board and volunteering web developer	Primary community platform, news and events, newsletter and member communication (substitute Google mail and MailChimp), managing shifts, community documents, statistics, member overview, online web shop (Substitute payment and ordering at the community space), supporting the work related to Thursday activities (substitute Google Drive)
Community Laptop	Donated by member	Used to access community website each Thursday
Community WiFi	Bought November 2015	Used to access community website each Thursday

Table 9.4: The community artifact ecology as it is envisioned in the third stage.

> *"[...] the hope is, that when we get the new website, that we'll be able to, like nudge people to actually fill in the shifts."* (Robert)

It will also take out the frustrations of the working group by introducing the possibility to automate the tedious and 'unfun' task:

> *"The more you can get those tasks done automatically, then you don't need to have a member to do this. Because people are working voluntarily and that is the hardest thing to get volunteers for. So the more you can clean away of that, just run automatically, the better."* (Laura)

At this stage, there was a certain fatigue among the members, and the concern was very much with the 'drill' or the running of the activities. In this current stage, the members are starting to focus on making the existing management more efficient and easier, and on consolidating many of the small practices and systems that were developed within the work groups and across the community artifact ecology. The current focus is on a vision that should make a lot of the existing tools obsolete and/or an integrated part of the new website. In table 9.4, we have summarized how the interviewees envision how the community artifact ecology will look like once the new website is operational.

9.7 FINDINGS: COMMUNITY ARTIFACT ECOLOGY – MULTIPLE, DYNAMIC, AND NECESSARY

In order to further explore how artifact ecologies support the community in question, this section looks in further detail at some of the particularities of the community artifact ecology through the theoretical framing outlined above. In particular, the focus will be on the three research questions outlined in the introduction: What is a community artifact ecology? How is it shaped? And what role does it play in the development of the community?

Multiple overlapping ecologies

As we have seen in our analysis, the community artifact ecology of the particular community initially took shape from the personal artifact ecologies of the founding members and the elements 'imported' from the community in Copenhagen. Later, as the community website was developed, this soon became a central element of the community artifact ecology. As the website caused both technical and practical challenges, members of the working groups introduced new tools and adapted elements of the existing in order to continue working. All of this has lead to the community artifact ecology consisting of several overlapping ecologies, with different historical trajectories.

First, parts of the community artifact ecology were associated with the different activities within the community, e.g., in the very beginning, communication was handled via Facebook, while later being separated to handle the need for internal communication, both among the community members and to the member base at large. Currently, external communication is done via a subset of the artifact ecology, in particular social media and the front-page of the website, while internal communication is handled via emails and newsletter's to the members. These groupings of artifacts, defined partly by their purpose, resemble what Jung et al. [191] found in relation to personal ecologies. Grouping artifacts based on their purpose and actively substituting or supplementing particular artifacts as issues emerge, we see in multiple instances. Similarly, subsets of the ecology are activated around particular activities. The most obvious example is how the community members setup the laptop, credit-card terminal, WiFi and spreadsheets each Thursday to support the core community activity. This resembles what Rositto et al. [307] refer to as aligned constellations, i.e. a potential subset of the community artifact ecology that is active depending upon the time, place and activity. So while the community has a community artifact ecology, it is not active at all the time for all members, yet there are acknowledged and decided ways of setting up and doing certain tasks, from publishing minutes in the members only section, over handling the orders that go to the farmer, to setting up the workspace each Thursday.

Second, the community artifact ecology is comprised of multiple overlapping ecologies, stemming both from individual members, related communities and groups within the community. Key-individuals influence the community artifact ecology by introducing artifacts from their personal ecology, artifacts they have some familiarity and experience with from elsewhere. As seen above, parts of the particular community artifact ecology originate from a similar community in Copenhagen, and table 3 indicates that the communication group played an important role in influencing the community ecology. This happened through the introduction of a communication strategy, newsletter service, various social media and the credit-card terminal. So, the idea of more capable peers, introduced by Bødker & Klokmose [55], or Rositto et al.s' [307] proposers, *can be expanded beyond individuals to include more capable (or experienced) and related communities and active groups within the community itself.* The most prominent example is that of the founders and their influence in shaping the ecology, while they established the community. Other examples include deciding the underlying CMS system for the website, based on personal, professional preferences, or fixing an unsatisfactory situation by introducing a different email service. Artifacts from other ecologies got introduced from other communities, here exemplified by the initial adoption of the Copenhagen Wikispace and specific parts of the organization introducing new tools to handle payment or communication. This happened both *slowly, with artifacts being imported and adopted more permanently*, through conscious introduction from within the community, as well as through *on-the-spot quick reactions*, such as when community members invested their personal devices as a WiFi hotspot.

Third, bits and pieces of the artifact ecologies of other communities or key-members got included into the artifact ecology of the community. These would linger on, even after the members became inactive or left the community. For example, the Wikispace stayed in the ecology for as long as until mid 2014 for a particular working group. Also, Facebook and Google Drive, which were part of the personal ecology of the founding members, are still part of the community ecology, although these members have resigned from their position in the board and working groups. Substitution has happened when the different artifacts slowly transitioned and changed role as other artifacts replaced part of their functionality, see e.g. table 9.2 and 9.3. The artifact ecology thus has become stable and established in the community practices and the community space, in the same way as both Nardi & O'Day [268] and Bell [35] talk about information ecologies, namely as places and particular local cultures developed through participation in and around practices. *While individual members move on, the artifacts become part of the community, as a shared understanding of the community and their practices.* Nardi & O'Day go as far as saying that an information ecology has a place – it is a particular habitat identifiable by the inhabitants, here the community members.

Shaping and changing a particular ecology

In our case study we have identified multiple examples of different ways in which community members engage in shaping the community artifact ecology, in relation to or as part of the core community activities. Shaping the ecology has taken place through a combination of on-the-spot reactions and workarounds and longer-term strategies, depending on the situation at hand and the members involved. From the empirical data we learned that despite being a very open community, it has nonetheless been a small percentage of members who are and were actively involved. This also translates into their involvement in shaping the artifact ecology. Some of the more casual members, whose involvement extended to taking part in the Thursday shifts, have resorted to tactic-like workarounds, such as connecting the credit card terminal to their own laptops and mobile Internet connections. However, it is the smaller percentage of members, active in working groups and organizational boards that were more strongly influencing the community artifact ecology. They were directly influencing what tools were adopted in the working groups, and they usually participated in the community meetings, where bigger IT-related decisions were taken (e.g. regarding the new website).

Other influential members were naturally the founders who got a big say over the initial constituents of the artifact ecology, as with the design of the first website and the introduction of Google Drive, where personal preferences such as ease of use played an important role. These personal preferences went beyond functional ones, to include more reflective values, such as being more user-friendly or giving a more professional and coherent image, as also noted by Jung et al. [191]. Second, the skilled 'IT guys' played a defining role with regard to the website. While the founders had a privileged position, the web developers each had a privileged position in shaping the ecology through their proficiency and ability to develop a tailor-made solution. Personal preferences still played an important role for that, albeit on a different level. While the rest of the core members knew the applications quite well in terms of general role and functionality, the IT-guys knew the software and applications on a more technical level, as software components, application interfaces and code. Here, the personal preferences were present as favoring one CMS system over another, based on familiarity with one system over the other. The founders stood out as very capable of assessing and working with a variety of online tools, whereas the two IT-guys additionally introduced a finer-grained level of operating technology, at the level of software code, as one additional way of shaping the ecology.

'A farmer, a place and at least 20 members' *and* a working artifact ecology

The advice given by the Copenhagen organic food community representative, to find a farmer, a place, and at least 20 members, made it possible to start an organic food community. The two women who wanted to found a similar community in their city followed this advice, and it worked for them too. However, from the very beginning, they also worked on establishing a working artifact ecology. It was by establishing this initial ecology (a Facebook page, Google Drive, a wiki, and their own website) that they got in contact with a farmer, started organizing the orders, and got a place to distribute the food, as well as interested members to join.

The artifact ecology then went into a continuous process of evolution, and it still is, today; a defining trait of a healthy ecology as Nardi & O'Day argue. The road has been filled with many frustrations, related to things not working or features not being implemented. By resorting to new additions and workarounds, the artifact ecology eventually reached stable situations where it supported the various activities of the community; maybe not in an ideal ways, but as getting things going and enabling the community to continue what it does and what it needs to do to get fresh local organic food at a cheap price, through collaborative volunteer work. At the same time, the vision of a new website has always been there, even acting as a pacifying filter to existing tensions and frustrations. When the concrete development work started with the second volunteering web developer, it also pulled the community together in the joint effort of deciding on features and specifications. The second volunteering web developer, who is now developing the new website, has been a member of the community for several years and has been doing patching-up work to the artifact ecology. With this rooting, the shared vision of the new website became an instrument of the process of shaping the community itself. This is parallel to the way the community comes together on Thursday afternoons to make the space at the residents' house look like the organic food community space: Members, volunteering for shifts, try to make the space feel cozy, clean and inviting; the recipe working groups sometimes brings in goods that they have prepared, etc.

The process of envisioning, designing, and developing the new website thus became an important element in shaping the community, just as the process of creating the initial logo, a Facebook page and the first website was an important part of creating the community in the first place. The fact that it could be tailor-made, made the vision reflect the way at least key community members viewed their community, and it provided a vision for where they wanted the community to be (easy to order, user-friendly interfaces, efficient to manage and even make community management 'fun' again), and how ultimately they would get rid of some of the mess of the current more ad-hoc artifact ecology. However, the vision of the new website is not the 'holy grail'. The process of the community coming together around the vision of the shared website was made possible by the stabilized working artifact ecology. Things neither needed to come to a hold because everything was not working perfectly, nor because a new website was being developed, yet the vision of the new, more perfect solution made the current situation endurable somehow. The artifact ecology was and is patched together, and the temporary aspect, and the temporality as such, of the patching up, are accepted, *because* a new solution is being worked on. Just as Nardi & O'Day [268] note that there is never a perfect fit, Bødker & Klokmose [55] outline never ending movements between the unsatisfactory, exited and stable state, and Rositto et al.s' point to the performative nature of making constellations work, so does our study indicate, that *the community artifact ecology is in equilibrium, yet dynamic and always the object of some community work*. It may even be a *fundamental condition of collaborating* in a self-organized community that is based on volunteer work and scarce resources.

9.8 Discussion

As the community grew, so did the effort that had to be put into managing and supporting the weekly activities. The work of maintaining the community artifact ecology grew as the community grew. This is not unlike the work that goes into maintaining any organizational infrastructure [287], and table 9.3 and 9.4 indicate some division between external communication, community management and the artifacts used each Thursday. While we do not see community artifact ecologies as infrastructure per se, they do contain elements of infrastructure (e.g. WiFi) and artifacts that exhibit infrastructure characteristics, e.g. by being standardized and multi-sited, such as email and calendars. Community artifact ecologies are dynamic and very particular to a specific community, in contrast to how infrastructure is viewed. They spring out of a complex historical mix of influences from multiple other ecologies, co-evolved with the practices of the community, bound by both culture and place. Still, the *work that goes into making the ecology work* (cf. [67, 307]) could be described as *infrastructuring*, with local adaptations of familiar artifacts, introduction of new, inertia and tensions as fundamental conditions for community work. Issues may rise between the primary activities and managing the community artifact ecology, as we have seen with the fatigue reported above. Whether this is a consequence of having multiple artifacts in play or the issues are introduced by the dynamic trait of ecologies (cf. [55, 268]) is an open question.

In our presentation of the case we outlined three stages in the formation of the community and its artifact ecology: Becoming a community, everyday community work, and building anew. These stages are meant to be use descriptively, not prescriptively, and they cover the time from the initiation of the community until writing this publication. However, our studies indicate that a large part of community artifact ecology is established in the initial stage of the community, and often co-created with the community, by the few founding members. Accordingly, paying attention to what and how the initial ecology is negotiated and decided upon when the community is formed, is important if one wants to understand how the community artifact ecology and the community co-evolves as well as some of the implications introduced in this early stage. The initial creation of the community artifact ecology by the founding members, resemble the performative act of aligning a particular groups constellation as described by Rossitti et al. [307]. Once the community is established and the primary activities are stabilized (in our case ordering and distributing organic food), the states presented by Bødker & Klokmose [55] may be more descriptive of what happens around particular activities and situations, and the subset of artifacts involved. The different states become more visible in and around well-established activities. The unsatisfactory state of internal communication is one example, and the stable state of artifacts that make up the workspace each Thursday is another. The states do not cover the whole of the community artifact ecology, rather, they emerge around specific activates and artifacts within the ecology. This may create tensions that, over time, propagate to involve the entire community artifact ecology, as members become frustrated with a larger and larger subset of the community artifact ecology, as we have seen in our study. The frustration with multiple artifacts and an increasing prevalent idea, that a new consolidated community platform would mitigate the frustrations and overhead involved in managing the community, created a tension that resulted in paying a community member to develop a new website (and challenging the volunteering characteristic of community). Understanding the dynamics and states introduced by Bødker & Klomose, on a community level is an important part of understanding how such a community artifact ecology evolve.

The setting we present here is that of ‘CSCW in the wild.’ [85]. We are well aware that studying CSCW in the wild and in particular when studying a single community, results in a similar particular and partial picture of the community artifact ecology, it's genealogy and role within the community. The findings outlined above, the particular constellation of artifacts and 'stages' of the ecology, pertain to this particular community and can not be generalised to all communities. We do try to argue for a more abstracted contribution in theorizing on the concept of community artifact ecologies and the intersections between the personal artifact ecology and the share and more common artifact ecology. Whereas much focus is usually placed on understanding the way CSCW takes place through the use of particular technologies, or how technologies should be set up to support collaborative communities, our analysis and findings show that much can be learned from observing communities shaping themselves their own collaborative environment – here with the emphasis on shaping rather that just using: Communities with little resources are creative in shaping their artifact ecology, making use of existing mundane tools, but also creating specifications for software they need and finding ways to finance their development. However, our example also shows that these solutions can strain communities, as they require their own share of volunteer work. This places this kind of research in a somewhat challenging position, especially concerning our role as CSCW researchers and designers. We have chosen to undertake our research using the concept of artifact ecology because it provides a solid framing for exploring the interaction that a community has with and through a multitude of tools. Many of our findings, however, also echo the current discussion on infrastructuring, as it is taking place e.g. in the field of CSCW and participatory design (PD). Whereas the more recent discussions within PD tend to place the role of (professional) designers in prime position, so as to discuss their action possibilities, methods and responsibilities (e.g. [224]) older work such as that of Karasti & Syrjänen [195] has emphasized the design work of communities themselves, pointing more directly to the appropriation of artifacts and the development of resources *by* the community. This points to a different role for the researcher (who is engaging with a community through action research and participatory design) rather than the moral commitment to 'fix' community problems (see [51]).

9.9 Conclusion

Our case study shows an example of how a self-organizing volunteer-based community uses a collection of tools to both manage the community and their primary activities related to ordering and selling local organic food to the community members. Our findings have shown that the artifact ecology of a volunteer-based community is multifaceted, consisting of overlapping ecologies, and is shaped by key members, related communities and internal work groups throughout the community lifespan. The community artifact ecology co-evolves with the community and is shaped by changing needs, while also creating tensions within and straining the community. In this specific case the community artifact ecology did support the community in their work, while also being the source of both frustrations and requiring work to make the community artifact ecology work. Work we hypnotize is a fundamental condition of collaborating in this type of communities. Based on the case study and existing research on artifact ecologies, we propose the theoretical concept of community artifact ecologies as the particular constellation of artifacts that a community owns, has access to and uses in its activities. It is characterized by a high degree of shared understanding of the core activities and the role of the artifacts within the ecology. It changes throughout the community lifetime in response to community needs. This occurs both through explicit negotiation and more subtle adoption of artifacts originating from the ecology of individual members, often more capable peers. It is both dynamic, as it co-evolves with the community, and stable beyond the individual member. While particular artifacts may stem from individual members, they are often adopted by the community and become part of the community practices and shared history.

9.10 ACKNOWLEDGEMENTS

We would like to thank Aarhus Organic Food Community and the participants for allowing us to conduct research on their community. The research is funded through the Aarhus University interdisciplinary centre PIT.

Chapter 10

Publication III: Happenstance, Strategies and Tactics: Intrinsic Design in a Volunteer-based Community

Happenstance, Strategies and Tactics: Intrinsic Design in a Volunteer-based Community

Susanne Bødker, Henrik Korsgaard, Peter Lyle and Joanna Saad-Sulonen

Abstract

This paper presents the study of a volunteer community, its technologies, and the processes in and through which it develops, sustains and makes its community artifact ecology work. Based on previous work proposing the concept of community artifact ecology as a way of understanding the constellation of technologies a community owns, has access to and uses in their practices, we examine the dynamics and development of such a community artifact ecology in detail. The findings indicate that in volunteer communities developing a working community artifact ecology is a process mixing happenstance, community strategies and everyday tailoring and appropriation tactics. Additionally, much of the design and infrastructuring work in shaping the community artifact ecology and making it work both blurs with use and can be considered as intrinsic design as it is conducted by members of the community, with no input from the outside. Based on the empirical findings we expand on multiple positions within the theoretical space of design-in-use and intrinsic practice transformation mediated by technology and conclude with a more multi-faceted understanding of the shaping of technology in volunteer-based communities.

10.1 Introduction

Information Technology is an integrated part of community work and organisation. As everyday coordination and communication in urban and local communities move onto online platforms, these communities adopt and appropriate existing technologies to support and manage their practices. We have previously characterised the collection of tools and technologies a community owns, has access to, and uses to support their practices as a community artifact ecology [61]. Making the community artifact ecology work is a challenge as volunteer-based communities operate with few economic and human resources, often disproportionately distributed and dependent on when and how members can contribute [e.g. 234]. As a result, they tend to favour free or readily available technologies, and often need to combine existing technologies, adapt or develop new tools, or become dependent on technology adept members. As a consequence the process of making the community ecology work can be characterised as complex, combining happenstance, with strategic community efforts and everyday appropriation and tinkering. This is the frame wherein we position our research questions: How does a volunteer-based community develop their community artifact ecology throughout their life-cycle? What is the role of community meetings and everyday appropriations in shaping technology? And, how does this unfold as a continuous interplay between happenstance, strategies and tactics? In an effort to address these questions we have followed a volunteer-based organic food community in Aarhus, Denmark, from 2014 to 2016.

Whereas our previous work has focused on understanding the community artifact ecology and the interplay between the development of a community and the tools they use, this work confronts empirical findings with several frameworks that address the relationship between design and appropriation/design-in-use: Dourish's [109] adaptation of De Certeau's [87] notion of strategies and tactics in relation to design, Wulf & Pipek's [287] points of infrastructure, and Kaptelinin & Bannon's [193] intrinsic versus extrinsic practice transformation. Based on our analysis of the empirical material, we point out that a richer set of concepts and understanding is needed to fully appreciate the variety of design-in-use happening in this complex setting, where volunteering work over a long time-frame is inter-woven with decisions about adoption and appropriation of technology. The contribution of this paper is a) a detailed examination of how a community develops its community artifact ecology, b) to identify the role of community decisions on technology, c) the various everyday tactics employed to make the community artifact ecology work, and d) to expand on existing understandings of how technology development at large unfolds in volunteer-based communities around points of infrastructure, in particular the model proposed by Wulf & Pipek [287, p.458] and the concepts discussed by Kaptelinin & Bannon [193].

10.2 Background and Related Work

In the following we reiterate previous conceptual and theoretical work on community artifact ecology and present the primary frameworks on intrinsic practice transformation and appropriation and design-in-use. We will return to this after analysing the empirical findings and position the implications of our findings.

Community Artifact Ecology

A community artifact ecology is the particular constellation of artifacts that a community owns, has access to and uses in its activities [61]. This concept draws on work on personal artifact ecologies [55, 191], i.e. artifacts that an individual uses and owns, and information and cultural ecologies [35, 268], i.e. place-specific constellations of (information) artifacts belonging to and/or available within a particular context. Artifact ecologies are dynamic and change over time – individuals learn new tools through peers and practices. Practices and places change in terms of the information resources and technologies available [55].

In previous work [61] we found that a specific community artifact ecology originate from multiple overlapping ecologies, e.g. the artifacts that individuals bring into the community, inspiration from other communities, what is available in the community space and dictated by resource constraints etc. When a community is founded and/or decides on the specific tools the community will use these to support their practices (e.g. common social media platform, web-applications, shared repositories, a website etc.), the tools and knowledge thereof originate within the personal ecology of the deciding members, similar communities and/or general tools, e.g. a credit card terminal. The artifacts belong to the community, e.g. in ownership or as embedded in their practices, and the artifacts are 'somewhere' – in a shared community space, virtual and physical. This process is ongoing as new tools are introduced, as the community and its practice changes, and as new members move from the periphery into the core activities. Although new tools are introduced into the ecology over time, the older artifacts tend to linger. These lingering tools are due to a dependency (actual, or a familiarity) by members for specific activities, and the difficulty of consolidating the disparate tools and (critical) information hosted or embedded within these. The result is a community artifact ecology with a complex genealogy and multiple overlapping ecologies, activated as part of particular community activities (events, accounting, managing members, communication etc.).

Intrinsic Practice Transformation and Community Design

In design and adoption of information technology, Kaptelinin & Bannon [see 193, fig. 4] distinguish between extrinsic and intrinsic practice transformation. Extrinsic practice transformation is primarily performed from the outside and is driven by designers. By contrast intrinsic practice transformation is initiated by users, is continuous, directly relates to the practices and activities at hand, and results in idiosyncratic designs. Intrinsic is driven by needs of the users, or an imbalance between the current setup's capabilities and the users' needs/wants. Intrinsic and extrinsic are not mutually exclusive, and, as we shall see, can be interpreted as a continuum. In the vocabulary of Kaptelinin & Bannon, extrinsic is closely linked to the process of user-centred design and iteratively moving through and analysing the existing practice with the aim of developing and introducing an artifact that will transform this practice (at a later state). Intrinsic practice transformation, then, is more akin to design-in-use and appropriation where people are *"more concerned about how to use all available resources, including interactive technologies [. . .] to further develop their practices and improve their environments."* [193, p.287]. Dourish [109] offers a related perspective in his adaptation of De Certeau's [87] concept of spatial strategies and tactics, stating that *"strategic practices are the practices of design, whereas tactical practices are the practices of use."* [109, p.302].

Design-in-use and Infrastructuring

As community activities and practices stabilise, and in particular when the community is anchored in a shared physical space, its community artifact ecology can be characterised as an infrastructure and the dynamic aspects of the community artifact ecology as infrastructuring [322, 333]. However, the dynamic, disparate, and evolving character of the community artifact ecology is far from artful, and as we shall see, not envisioned as the primary object of work or design, although taking up considerable community attention. Nonetheless, research on infrastructuring provides a useful anchor for analyzing the dynamics of the community artifact ecology. Pipek & Wulf [287] present the *point of infrastructure* as the point in time where general development and specific design processes meet use (and development in use). To them, tailoring is the technical development, and appropriation the practice development that happens in use, after the point of infrastructure. Before that lies both general technological and organizational development, and specific design projects.

Henderson & Kyng [174] referred to *continuous design in use* to address the expansion of design into the realm of use. Design-in-use refers to design activities that happen after professional or preparational design activities have taken place and after a designed artifact has been deployed into use [106], or *intrinsically* as per Kaptelinin & Bannon [193]. Design-in-use can be understood as an umbrella concept that includes activities such as appropriation, tailoring, and adaptation, a familiar topic in Human-Computer Interaction (HCI) and related areas. The traditions of tailoring and end-user development have a long record of studying both how users pick-up and use/reuse technologies built by others, how technologies may be build to support such development, and the roles and competencies of various groups of people.

Happenstance, Strategies and Tactics

Instead of concluding that extrinsic practice transformation are strategies and intrinsic practice transformation is tactics, or that infrastructuring is a solely strategic endeavour, a matter of planning and deciding, we summarise by outlining simple distinctions that are analytically useful in the present case.

Happenstance encompasses not only events and circumstances related to the potential and particular community artifact ecology, but also the external and internal conditions under which it is stabilised around points of infrastructure. In their early studies of tailoring and use of CAD, Gant & Nardi talked about gurus and gardeners as roles that emerge during design-in-use [133], and McLean et al. about how the tailors (or tinkerers) live on the plains of competencies in tailoring [238]. In that light, happenstance include the people who happen to be there and take on the work to make the community work and define the role multiple technologies play – implicitly through activities or explicitly through community decisions.

Strategies are design activities intrinsic to the practices of the community, that are directed at, but momentarily detached from the activities at hand. Strategies are the design activities that a community engages in collectively in more formal community meetings when discussing issues, concerns and future needs. By contrast, tactics are situated activities attempting to deal with happenstance as well as changes occurring in everyday community practices. Both encompass *articulation work* [312, 323]: The secondary activities needed to divide, allocate, coordinate, schedule, mesh, and interrelate work activities. Although articulation work occurs both in situated activities and related community meetings, it is a useful concept to understand the role of community meetings in relation to community design of technology as strategies. Tactics are closely related to the everyday activities, and as Dourish points out, a way of reacting to plans and designs, made outside the immediate situation. In relation to the work presented here, it becomes interesting to understand how appropriation and design-in-use happens in artifact ecologies at large (see also [53, 55]), and in community artifact ecologies in particular, as a complex combination of happenstance, strategies and tactics.

10.3 Case Study: Aarhus Organic Food Community

Aarhus Organic Food Community (AOFF) is a local organic food community active in the city of Aarhus, Denmark. It was founded by two women who wanted to have alternative and cheaper access to local organic food. They initiated the community in late 2010 and were inspired by the practices of a organic food community established in Copenhagen. The main activities of the community consists of ordering vegetables and eggs on behalf of their members from two local farmers. Members cannot choose what vegetables they will get, but instead place orders for receiving a bag of vegetables. The selection of the bag content is done by members of the purchasing group, who decide what can be covered by the fixed bag price for all members. The farmers then deliver their goods each Thursday to a local community center where the community distribute the goods. Some members volunteer for the packing shift to make goods available for all members to both pick up and place new orders. Since early 2016 the community has introduced a web shop on their new website where it is also possible for members to order their bags online beforehand.

AOFF is also a legal entity in the form of a registered association which requires a board, by-laws and a yearly general assembly. The community is highly organized with their board plus seven working groups who managing the community, arranging events, coordinating with authorities (permits and hygiene inspection), buying and coordinating with the local farmers, and then selling and distributing the organic food goods to the ordinary members of the community. The board and the working groups represent a stable core membership base of approx. 40 volunteers, while the wider community consists of approx. 900 registered members. They pay a fee upon joining the community and are required to volunteer for three hours each month, coordinated through a scheduling tool on the community website. The community organization is open to all

Period	Function	Artifacts
c.2011	Communication	AOFF.dk (v1), Facebook, Email
–	Organisation	Wikispaces, Google Drive
c.2013	Thursdays	
c.2013	Communication	Facebook, Twitter, Instagram, MailChimp
–	Organisation	AOFF.dk (v2), Google Drive, Google Mail
c.2015	Thursdays	Community Laptop, Google Drive, WiFI, Credit Card Terminal
c.2015	Communication	Facebook, Twitter, Instagram
–	Organisation	AOFF.dk (v3), Google Drive
c.2016	Thursdays	Community Laptop, WiFi, Swipp, Mobile Pay, AOFF.dk (v3)

Table 10.1: AOFF's Community Artifact Ecology in different stages.

members, with weekly meetings in the working groups, monthly community meetings and an annual general assembly. AOFF emphasise that every decision should be made democratically. Issues and decisions are presented to the community in agendas distributed to all members beforehand and minutes are shared in the members section of the website.

In [61] we describe and discuss the technologies deployed over time by the community, in what we term the community artifact ecology. Three stages were identified where different members of the community and its board have been instrumental in activating (introducing, tailoring and 'hacking') various technologies that were brought in from elsewhere. We report on the technologies in table 10.1, divided into three stages. The first stage refers to the initial steps in shaping the community and its artifact ecology; the second stage refers to the everyday community work, once the community was established, and the kind of everyday appropriations that took place; and the final stage is the vision of the future and the steps taken to overcome frustrations.

10.4 Methodology and Data

We have followed AOFF activities since autumn 2014, when one of the researchers joined the community. Since then, we have engaged in participant observations, interviews, and content analysis of online material produced by the community. For this study, we utilise data from the minutes of community meetings (kollektiv møder)(N=56 between 2011 and March 2016), as reported in the members' section of the community website, and a series of interviews conducted between 2014 and 2016 with six core members of the community, who had some involvement in technology-related decisions or activities (see table 10.2). The interviews were semi-structured, transcribed and analysed through meaning-condensation [219]. The key identified events and relations from the interviews was subsequently compared to the events and details captured in the meeting minutes. We were granted permission by the board members to use data from the minutes, as long as we render our reports anonymously, make no direct citations, and do not openly

Name	Role(s)	Membership	Length
Laura	Founder work group and board member	2010 – 2014	01:07:05
Karen	Work group and board member	2012 – now	01:09:48
Nadia	Work group and board member	2011 – now	00:48:31 (01:09:48 follow up)
Robert	Work group and board member contact to authorities	2011 – now	00:54:48
Paul	Work group member web developer	2011 (active 2012) – now	01:02:19
Christine	Work group member web support	2013 – now	00:54:11

Table 10.2: Interviews and respondents role within the community

refer to specific personal conflicts if such were reported in the minutes. In cases where dates and chronological events are described inconsistently in the interviews, the meeting minutes are considered authoritative.

To underline the empirical grounding we report the results separately before extending the findings with our analysis in the following sections. We draw on multiple theoretical constructs to drive our analysis: strategies and tactics help to frame three example technology-specific processes and identify the role of happenstance; points of infrastructure provide a frame to denote aspects of these technology-specific processes, presented concurrently along a timeline; and, the distinction between extrinsic and intrinsic design is explored in contrast with the roles and actions of community members.

10.5 Results

We present the results of our empirical investigation in the following two subsections, creating a distinction between the types of activities that relate 1) to community decisions on technology, often undertaken through a formal process embedded in their democratic decision-making mechanisms, and 2) to everyday tailoring and appropriation operations, which take place in different situations and depend on the technological skills of those undertaking them. The community decisions presented are primarily informed by the community meeting minutes and supported by our qualitative interviews, whereas the everyday actions are based solely on the interviews.

Community Decisions on Technology

As soon as AOFF became an organised association they discussed, in their community meetings, the tools and technologies they use, need and envision. The minutes of meetings show a steady use of updates, feature requests for the community website, additional tools, and reactions to changes. The first meeting began with an update on the initial design of the first community website, and the last reviewed meeting minutes fittingly announce the newest version of the website (their second website), which includes a webshop feature. Decisions on key aspects of the community artifact ecology are evident throughout the minutes and important decisions on payment, design and features have been debated and voted on at the community meetings. When put on the agenda, each proposition is dealt with and discussed toward some form of outcome, a decision or rejection of the proposal.

Suggestions and Features

Throughout the last 5 years of community meetings we see multiple instances of leading community members suggesting features and additions to the website and other aspects of the artifact ecology. These vary from proposing the procurement of a community laptop, a desire for accounting software, to various changes to the website's features and content. As early as 2011 the community discussed online ordering and payment via the community website features. Later, features such as shift reminders, an online news feed, and enabling online member sign-ups were suggested. Some of these suggestions never materialised, others have later become part of the community artifact ecology without being further mentioned at the meeting, and finally some resulted in longer investigations leading to formal decisions made at later community meetings. For example, in 2014 during a meeting, there was discussion regarding procurement of a laptop for the community space, and later we learned from the interviews that a member subsequently donated her old laptop. When it comes to proposing features, which seems a recurring element at the community meetings, some are forwarded to the member acting as web-developer, while others are rejected, often based on existing initiatives, e.g. not adopting a new payment model while in the process of examining webshop functionality. One of the major frustrations regarding feature implementation, as came through in the interviews, was that the member who actually implemented their first website, later became less and less interested in the community, to the point of being unavailable for updates and maintenance.

Initiating Processes

A second function of the community meetings in relation to technology and formulating strategies is initiating processes. Although slow progress is a fundamental constraint in a volunteer-based community with few resources, the discussions at the community meetings indicate a careful position related to larger decisions. For instance, adopting, and later changing, the options for accepting payment was initiated as a lengthy process where a member acting as their main accountant examined the costs and options. This was done in three different phases: 1) as part of the initial explorations of the possibility of a webshop (2011), 2) as part of choosing between credit card payments and competing mobile technologies, and 3) as part of the much later introduction of the webshop in 2016. Similarly, the community was invited to participate in applying for funds for a national IT platform for food communities, an initiative discussed in 5 meetings spanning 10 months. The community agreed to participate in the funding application, and later in the process of developing a national IT platform for food communities[1].

Making Decisions

At the community meetings the participants make decisions affecting the community artifact ecology. In some instances this is visible as updates on the feature suggestions and the initiated process outline above, in other cases it is a result of a specific discussion raised within a shorter time frame. When the community was formed they decided to use a wiki as the primary community platform. Later, when presented with an opportunity to have their own website, their needs evolved, and they decided to close the wiki and use the newly developed website as the community platform. Throughout the lifespan of the community there were several options to accept payment in the community space, e.g. cash, credit card and lately different mobile solutions. In mid 2015 they made a decision on a specific payment solution for the webshop and in 2016 they decided to cancel the on-site credit card payment. From the minutes we have seen how these decisions are informed partly by the increased cost of maintaining the credit card option and the changes in available payment technologies since 2011. The community makes collective decisions regarding investments in technology and associated costs. The aforementioned decision on payment options and ongoing costs of hosting the website are all part of the budget and the community annual meeting, where the budget is approved by members. Similarly, when they needed to pay a member to develop their second website (2015), it was decided at an extraordinary community assembly.

Change and Uncertainty

As the development of the online payment and website slowly became a recurring topic at the community meetings, we see frequent updates on the status of the development or recognition that someone should contact the web-developer or responsible member. Frequent delays of work on the different iterations of the website were announced during the meetings, without community members initiating further investigation (as reflected in the minutes). When they moved away from the first website toward initiating a redevelopment process with a new web-developer, this appears abruptly in the meeting minutes. In October 2011 there is discussion of the status of the website and how they are in the midst of transferring multiple documents, and in November 2011 they propose the adoption of a new CMS system and transferring responsibility to a new developer, as the development of the initial website had been at a standstill for “some time” (this took about 18 months before the idea of fixing the first website was eventually abandoned). Although they made plans and discussed specific features repeatedly (webshop, online payment, member management), they also had to respond to changing circumstances, e.g. core participants’ lack of time to invest or even changes in technology. To summarize, community decisions on technology are often undertaken through

[1] eggplant.dk

a formal process embedded in the democratic decision-making mechanisms adopted by the community/association. Though formal, and on the surface somewhat rigid, it is also happening in an ongoing struggle with uncertainty and change in both available technologies and human participants.

Everyday Tailoring and Appropriation Practices

While many of the decisions related to technology are taken following a lengthy process and through the democratic design making mechanisms adopted by the community, we also find instances of everyday tailoring and appropriation. These are initiated and undertaken by a variety of community members in order to keep the core community activities running, despite breakdowns or happenstance. In the following, we identify hacks, substitutions and workarounds, rejections, and on-the-spot and in-time maintenance activities as examples of the kind of everyday situated actions when members *"have to be kind of creative to make things work"* (Paul).

Hacks

The fact that the first website was hosted on a server owned by the volunteer member who created the website, and the fact that this member eventually lost interested in the community, led to frustrations and resorting to hacks and workarounds. For example, in order to get a calendar on the first website, Paul, the member who later went on to develop the second website, *"went into the database and put in an iframe as a content element... that's not done through the CMS at all, that's just some... injected some SQL, into the database, which cause the calendar feature [...] but I mean, that's what we had, that's what we could do, it's the only possibility"* (Paul).

Paul also adapted the credit card terminal that the community came to use for a certain period of time. The community did not have access to the Internet via an Ethernet connection in the community space they were using. The problem regarded access to an Internet connection for the credit card terminal, whose model required an Ethernet plug. This was fixed by Paul hacking the community laptop in such a way that it would provide the existing WiFi connection to the credit card terminal, using the LAN-port of the laptop.

Substitutions and Workarounds

The same frustration emerging from the inaccessibility of the first website led some members to take matters in their own hands, and substitute existing website-dependent solutions to more flexible ones, which did not require significant technical know-how, but was based on experience with particular tools. For example, one member, Karen, decided to create a Google mail account for the working group she was a member of, as nothing could be done to fix the problems with the mail list associated with the community website.

Rejections

Rejecting the use of a particular tool is part of appropriation (see also [56]). It occurs when the tool does not automatically answer the needs of the users and the skills and knowledge of those handling it are insufficient for any form of adaptation, such as hacking or workarounds. For example, when the founding members started the community, they took the example of the Copenhagen organic food community and set up a wiki as their main online tool for communication and information. However, as they became familiar with the wiki, leading community members eventually decided against its use. According to a founding member, the wiki had usability issues and – in their understanding of the possibilities it offers – only allowed for public information to be posted, and did not support having a separate members-only section. Paul reported a different example: As members could not add documents to the first website, some of the working groups stopped writing their minutes of meetings all together. This affected the practice of keeping records of community activities and work, and created gaps in the community's archives.

These two examples of rejections have triggered design decisions regarding new systems. In the case of the first website, it was clear that it should offer what the wiki did not, which required a more user-friendly interface and a members-only section for internal information. In the case of the second website, Paul deliberately considered the writing of meeting minutes in his design decision: *"...the new system basically would sit and, it's going to be [an] adaptive layout, so you can sit with a tablet or your laptop and take notes on the website basically, and they will be saved and catalogued between the different groups..."* (Paul).

Maintenance

The inability to maintain the first website led to some of the hacks, substitutions and workarounds mentioned above. It also led to the strategic decision to create an entirely new website. However, as this new website was adopted in late 2015 and its online webshop was activate in early 2016, the question of who would maintain it was not completely solved. Paul, the member who had developed the second website, was clear that he did not have time to maintain it himself. The board thus placed an ad on their mailing list, Facebook group, and the new website to ask for volunteers to maintain the new website. One volunteer, a web content designer by occupation, answered. She was interested in doing the work because she was already familiar with Drupal, even though her experience with it was limited to using it for managing content. Being mostly on her own and with limited proficiency with Drupal, she has to come up with ways of dealing with the problems at hand, often as they arise. This involves *"mimic[ing] what has already been done, and when it doesn't work then you are like 'what should I do then?', also because I'm the one with the head responsibility."* (Christine). She also attempts to maintain contact, where possible, with others who might help, such as Paul (when he can be reached), the chairman of the association (who also has administrator access but no particular technical knowledge), and a member of a similar community from another town who implemented the webshop feature now in use by the AOFF website. Christine mentioned putting in around 10 hours a month on the maintenance work, which is much more than is expected of a normal member (3 hours). The time dedicated to maintaining the website had not been discussed prior to her involvement, nor did she know what to expect. However, one of the tenets of the community is that members would do as much work as they like and that no one should be forced.

The Formal and the Everyday

The above sections document the variety of ways through which the community comes to shape its artifact ecology. Our empirical research has looked at how this shaping happens: on the one hand in the context where formal decisions are made as part of the community's democratic mechanisms that rely on a flat hierarchy and consensus seeking in community meetings, and on the other hand through everyday tailoring and appropriation practices. In the following we look deeper at the ways these different activities are linked to each other, and across boundaries.

10.6 Happenstance, Strategies and Tactics

To understand how the community artifact ecology is shaped through a mix of events, community decisions and everyday appropriation practices, we examine the process and dynamic relationship around salient instances of changes occurring in the empirical findings. We return here to the notion of strategies and tactics, and examine three technology-specific processes where strategies and tactics interweave, which leads to a momentarily stable situation for one or more elements of the artifact ecology. Each of the instances are illustrated (figures 10.1,10.2,10.3) to show the relationship between strategies (top) and tactics (bottom), internal (black) and external events (white), and their direct (line) and indirect (dashed) relations. Direct relations are active consequences of decisions and events, whereas the indirect relationship are influences and indirect consequences.

From Wiki to Website(s)

Moving from using a community wiki to a community website stands out as an important point in developing the community artifact ecology. Throughout the first two years the community moved from using a community wiki adopted from a sibling-community, to engaging in design activities and developing their own community website. The wiki created and used from the beginning (a) (Figure 10.1), was later abandoned because they found the wiki model to be inconsistent with some of their needs. In particular the need to separate the wiki between a public section and internal private section that could service community tasks (b). In the same period, the community was contacted by a web-developer who offered to help them develop a community website (c). Thus, their perceived insufficiencies of the wiki coupled with the external offer created the foundation for a strategic decision to develop a dedicated website for the community

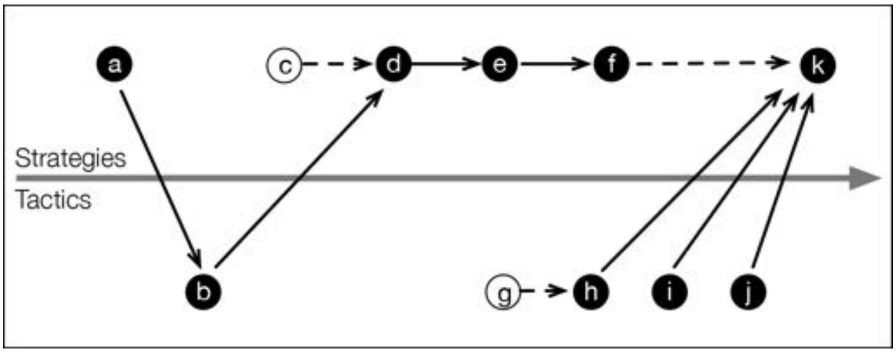

Figure 10.1: From wiki to website(s) process map (details in text).

(d), and later, when released (e), to start using it to support the community activities. Once in use, we see from the community meetings a steady flow of suggested features and a decision on developing a second iteration of the website together with the web-developer (f). However, the development and update of the website happened slowly and lasted around 18 months before it was eventually abandoned (g).

Meanwhile, community members employed different tactics to compensate for the lacking features, e.g. hacking the database (h), adopting another mailing list (i) or stopping the use of the website for meeting minutes, and for some working groups even stopping the practice of writing and archiving minutes of meetings (j). The main reason for abandoning further developments for the website and resorting to tactical operations was the fact that the initial web-developer became less and less involved with AOFF around 2011 and 2012, resulting in minimal development, slow communication and lack of access to the basic configuration on the back-end, forcing the community to "invent" alternatives around the website. Frustration with efforts to deal with the situation led to the community deciding to pay Paul, a member and also a web-developer, to develop a new website (k).

From Website to Webshop

The decision to abandon the first website and the ongoing process of updating it with new features was effectively decided at a community meeting (a) (Figure 10.2). The new developer made two key decisions: to base the new website on Drupal (the previous website was Joomla-based), and to adapt a component from the website of an organic food community from another town (b) and initiate a process where key members were involved in identifying, prioritising and helping with the list of features (c). "Importing" elements from a similar website were proposed as a way of keeping the code and website components more open (source) and potentially allow others to make use of the developed features. In April 2014 the community was approached by a national network of food communities about applying for funding for the development of a general IT platform for such communities (e). AOFF decided to participate (f), possibly influenced by the experiences with existing modules from other food communities (b) and ambitions toward contributing broader by making their own components broader available (d).

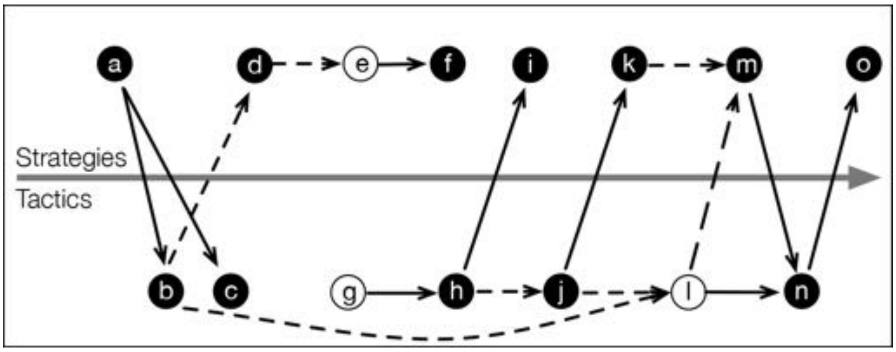

Figure 10.2: From website to webshop process map (details in text).

In October 2014 the web-developer realised how time consuming the task of creating the new website was and needed to prioritize other tasks outside his volunteering work (g). This lead him to suggest that the community would compensate him for his time by paying for the remaining development to ensure that he could prioritise this (h). This was approved in a general assembly in late 2014 (i). Later, the developer suggested launching the new website without the online shop (j), which was hesitantly approved by the community (k). At the same time the community they had taken inspiration earlier in the development process (b) released a beta version of their webshop (l). Getting the website almost done and ensuring delivery, and the possibility of adapting an existing component, motivated the community to begin recruiting for a new person to take charge of maintaining the website (m), and adapting the webshop module for their own website with the aid of the developer from the other community (n). The previous influence from the development process of the other community (b) seem to have motivated a subsequently adopting a webshop component developed by the same community (l). Early 2016 the community was able to announce that the anticipated webshop feature was finally ready (o).

From Cash to Mobile Payment

Our final example of the way in which these strategies and tactics map to the events and decisions of the community regards their support of different payment options (Figure 10.3). Managing payment often requires technical solutions to track expenditure and handle the ordering of stock. Initially the community only accepted cash, but recognised the need to provide more flexible options to their members. As early as July 2011 we see discussions in the meeting minutes that led to a desire to support multiple ordering methods, both online and at the physical location (a). It was however, not until September 2013 before the decision to acquire a credit card terminal was made. After a process of getting approvals from the relevant financial authorities, the device was acquired in May 2014 (b).

The terminal that was part of this procurement required a cabled Internet connection, where the onsite location only provided wifi. Concurrent to this process a laptop

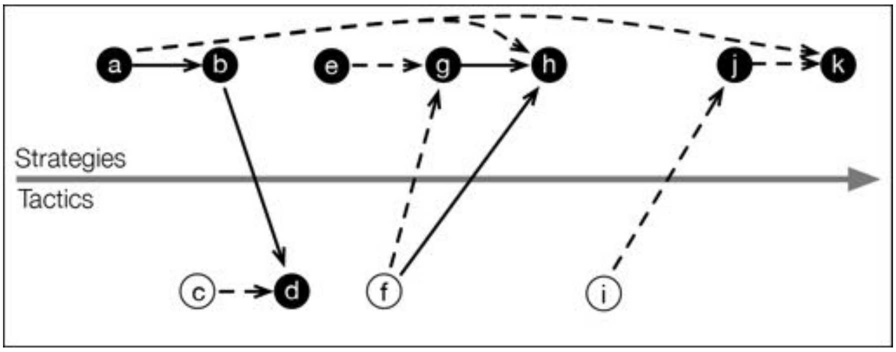

Figure 10.3: From cash to mobile payment process map (details in text).

had been donated by Nadia to the community to be used on site to assist with the logistics of signing up for shifts, ordering food and checking membership IDs (c). Paul was able to hack this donated laptop, where he configured it as a wireless access point for the credit card terminal (d). A year later in April of 2015, it became clear that the ongoing costs of the credit card terminal were too much for the community. While they could have reverted to the previous payment option of cash only, they recognised the need to support multiple forms for the convenience of their members (e). In addition, Denmark in general saw the release and success of mobile payment services (f). After investigating other payment options (g), they decided in May 2015 to make use of a mobile payment service. The credit card service was eventually ended late 2015, when the mobile payment facilities became active (h).

Paul joined the team, and the community's website was redesigned and developed (with the intention of providing online shopping facilities, but initially released without). (i) and (j) represent approximations of this process from Paul joining to the initial release of the new website, described above in the *From Website to Webshop* section. This continued and eventually in March 2016, a webshop, with online ordering that supports some credit card providers, was released (k). In an interview with the current technology support volunteer at AOFF, he indicated that there are ongoing discussions regarding the available payment options, and that there is some desire in the community to make payment accessible as convenience to existing members.

10.7 Infrastructuring Work in and Around the Community Artifact Ecology

We have shown in the previous section how strategies and tactics interweave in the way the community shapes its artifact ecology. Our analysis now takes a step back from the three technology-specific instances above and presents them together as part of a broader timeline of our research with AOFF's 'work to make its community artifact ecology work' (Figure 10.4). In creating this timeline we draw on Pipek & Wulf's [287] mapping of infrastructuring work and its different layers, and in particular at the way

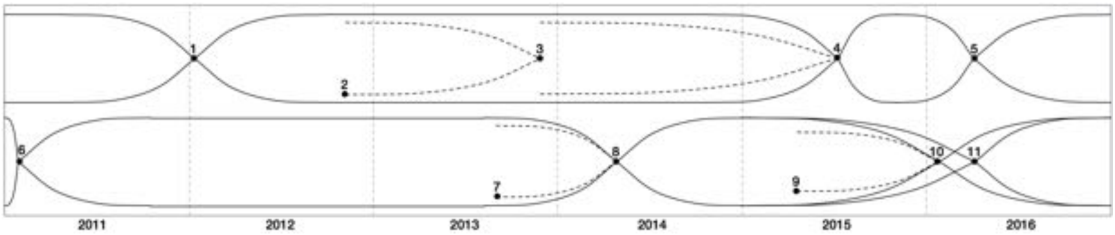

Figure 10.4: Overview of the community life-cycle and key infrastructure points. (Top) illustrating the processes related to the wiki, website and webshop, (bottom) illustrating the process related to the payment methods.

they indicate *points of infrastructure* as being those points in time where design meets use. The convergence of solid lines of figure 10.4 to a literal point represents identified points of infrastructure over time. The divergence after a point of infrastructure corresponds to the use and appropriation.

In the case of a volunteer-based community like the AOFF, we find multiple points of infrastructure that emerge out of combinations of strategic decisions and tactical tailoring and appropriations. Different to Pipek and Wulf's model, our case shows that the situation that occurs in the lead up to, and beyond a point of infrastructure, is not necessarily only that of receiving input, e.g. from infrastructural background work and preparation work, then having design-in-use activities following a straight line towards some resolution associated to the technology in question. This indicates that a point of infrastructure influences further discussion within the community and new emergent needs. A point of infrastructure shapes the ongoing process toward future points of infrastructure, with infrastructuring work dynamically unfolding over time. We have illustrated these influential circumstances in figure 10.4 with the dashed lines.

In Figure 10.4 (top), we first look at the infrastructuring work associated with AOFF's web presence. There, (1) represents a clear point of infrastructure as it denotes the moment when the first website is put into use. (2) is not an infrastructure point as per Pipek and Wulf's definition, but rather represents the eventual breakdown of infrastructure as there are plans and designs by the initial volunteer web developer which lead to (3). This represents a turning point - an abandoning of the iterative design of the first website as the initial volunteer web developer ceases involvement with the community (where there is a closure of the dashed lines), and Paul (having been involved in hacks and workarounds until this point) begins to lead a design process towards a new website (indicated by the new dashed lines that lead toward the next point of infrastructure). (4) is then again clearly a point of infrastructure, marking the deployment and initial use of the second website, albeit without the on-line payment feature. The launch of the on-line payment via webshop instead consolidates the next point of infrastructure, (5).

With regard to the decisions and appropriation of payment methods, we start with (6) of Figure 10.4 (bottom), which indicates the consolidation of practices associated with ordering and paying by cash on Thursday afternoons. Beyond this point is a period of debate and discussions in community meetings that culminate in a decision at (7) to take specific action towards obtaining a credit card terminal. This leads to (8), when the credit card terminal has been acquired and becomes part of their practice. (9) represents the growing concern about the cost of the credit card terminal, as well as the increasing availability of mobile payment services in Denmark. (10) represents a point of infrastructure where the mobile pay service becomes active and (11) denotes a point of infrastructure where a new release of the website (as per (5)), but from the perspective of the on-line payment system becoming available.

Our use of infrastructuring theory here has highlighted some of the complexities and nuances of how each point of infrastructure contributes to the next, and how the processes of making the community artifact ecology work is ongoing.

10.8 Intrinsic Design

The concept of infrastructuring makes it possible to explore the blurred boundaries between design and use. In the following, we return to Kaptelinin & Bannon's [193] work to examine in more detail the nature of the design work that we have observed within the AOFF community. Kaptelinin & Bannon [193] make a clear division between extrinsic (user-center design – UCD – based and introduced by an external designer) and intrinsic technology-enabled practice transformations (introduced and accomplished by 'users'). When examining these concepts in the case of AOFF, we can say that technology practice transformation there was mainly induced from the "inside", with no UCD or any other professional design influence. However, we have seen aspects of UCD-like activities, from the inside, with Paul attempting to engage others at a certain point of the design process of the new website. He organised workshops and invited interaction via a project management tool. However, this UCD-like intrinsic practice transformation did not require any of the traditional UCD phases of the designers having to get to know the communities and their practices, because Paul, as a community member, already had this intrinsic knowledge. Additionally, our case shows that some of the attributes of intrinsic technology-enabled practice that Kaptelinin & Bannon [193] present in opposition to extrinsic (p 286, Figure 4) are not so rigidly set if we look at intrinsic technology-enabled practices from within (so not in opposition to extrinsic ones).

For example, we may benefit from a finer grained terminology than Kaptelinin & Bannon's [193] 'designers' (extrinsic) and 'users' (intrinsic). We have community members, such as Paul, clearly and explicitly acting as a designer engaging in intrinsic technology-enabled practice transformation. We also have board members, and in fact any AOFF members taking part in community meetings and expressing opinions and voting on the adoption of a particular technology, thereby also engaging in intrinsic technology-enabled practice transformation. Kaptelinin & Bannon [193] also refer to extrinsic technology-enabled practice transformation as being discontinuous, in contrast to the intrinsic being continuous. We have shown however that continuity is not always a given in intrinsic technology-enhanced practice transformation. For example the decision of stopping the use of credit cards as a payment option on Thursdays ((h) in Figure 3) has brought discontinuity to certain purchasing and payment practices in the community. Finally, Kaptelinin & Bannon [193] emphasize generic designs in extrinsic practice transformation versus idiosyncratic designs in intrinsic ones. In the current study, the picture is not as simple: While Paul works intrinsically, he aims for general and generic solutions that can be useful to other communities, just like he and AOFF have benefited from the webshop feature of the organic food community of another town.

10.9 Discussion: Beyond Design and Design-In-Use

The fact that the study has focused on one particular community may be seen as a limitation, but on the other hand this choice of focus on a single community reflects the way this community sees itself. Despite the strong inspiration from and knowledge exchange with from similar communities, its members are very much aware of the specifics that make this community what it is: a combination of being local and of developing place-specific practices that fit the needs that emerge out of the local setting. Moreover, the very nature of volunteer work might be about idiosyncrasies that are perhaps more prevalent when participation is not driven by an employment contract but rather by an intrinsic motivation to do something because it benefits the community. This leads to a question to the HCI community: how do we account for this type intrinsic design related activities (whether of democratic decision-making, or of design proper or design-in-use in whatever form) that also induces change in practice?

Notions of design and design-in-use (which includes e.g. tailoring and appropriation, among other activities) seem different in the context of volunteer-based communities than e.g. in project-based work settings. In the latter, choosing, designing, and adapting technologies, are organised and happen around such organisational constructs as milestones, deadlines, and deliverables [e.g. 287], whereas in volunteer-based communities, such as AOFF, they happen to the best one can make them work, depending on interest and availability of people, on resources etc. Additionally, the shaping of artifact ecologies goes beyond notions of design and design-in-use in general, with democratic decision-making regarding technology, which is apparent in the AOFF case through their own practices in community meetings, playing a crucial role. Here, and contrary to traditional top-down management practices in organisations, decisions regarding technology are embedded in a setting driven by democratic practices. However, this also does not happen seamlessly, as decisions related to technology also require a certain level of skills and understanding of technical possibilities[238]. This means that many decisions are left to those who 'understand' better and have the necessary skills and experience. The difference and the challenge with information technologies are issues such as the need to maintain them over time, especially as the practices and people in the community change. The lack of access to maintenance is what killed AOFF's first website. It is still unclear how they will respond to their current maintenance challenges. How can volunteer-based communities account better for maintenance challenges? How could it be provided and what is the role of HCI?

10.10 Conclusions

In this paper we have shown how a volunteer-based community develops its community artifact ecology through a process mixing external circumstance (their *happenstance*), community strategies, and everyday tailoring and appropriation tactics. Most of the community strategies seem to have emerged through formal community meetings, where all those taking part have contributed to taking decisions. The tailoring and appropriation practices are tactics that have taken shape as results of unsatisfactory situations, using the set of skills of those involved. The interplay between happenstance, strategies and tactics as related to technological development unfolds throughout the lifespan of the community, around points of infrastructure, with things taking shape 'as they come', depending on the resources at hand and the people volunteering at a particular time, and whether these volunteers possess the skills and knowledge necessary to operate with technology at the required levels. Many of these activities can be understood as intrinsic design ones, undertaken by members of the community without interference from the exterior. Our study contributes to a more multifaceted understanding of the shaping of technology in the context of volunteer-based communities; A context, inviting the HCI community to look further into places where 'in house' and local design activities unfold, providing new insight on the interplay between design and use beyond the contexts of the home or workplace.

10.11 Acknowledgments

We would like to thank AOFF for allowing us to conduct our study. This research is funded by the Centre for Participatory IT at Aarhus University.

Chapter 11

Publication IV: InPlenary: Designing Systems for Co-located Active Learning in University Lectures

InPlenary: Designing Systems for Co-located Active Learning in University Lectures*

Henrik Korsgaard and Clemens Nylandsted Klokmose

Abstract

This paper explores the increasing use of personal computers by students in university lectures as a design space to support active learning. The design space is based on a literature review on technology use within the lecturing hall and a foundation on active learning, common information spaces and place-based computing. Through the design of a lecturing infrastructure, InPlenary, we demonstrate how to use existing infrastructure and personal devices to distribute the lecture presentation across multiple devices, embed learning activities within the lecture, use personal devices as an entry-point for active participation, co-develop the lecture presentation as a common information artifact throughout the lecture, and to couple users to an information artifact based on their connection to a wireless access point. Findings from using the system in four lectures are presented and discussed.

11.1 Introduction

Information technology plays an increasingly important role in university lectures. Today, lecturers use digital presentation tools and slideware (e.g. PowerPoint and Keynote) as part of lecturing and students bring laptops, tablets and smartphones into the lecturing hall as part of their study practices and everyday habits. This introduction of technology in the lecturing hall is, however, generating controversy between scholars, students and lecturers (see [316, 348]): Studies investigating the effectiveness of and benefits from using slideware are inconclusive [5, 31, 311, 334], the use of laptops and mobile technology within the lecturing hall may introduce an overhead related to multitasking and possible unrelated parallel activities [24, 30, 173, 184, 309]. With the rise of social media, notification based applications and an always online culture, the laptop and the smartphone becomes an increasing source of distractions and interruptions

*Draft in preparation for submission to the 2017 conference on Designing interactive systems.

[190, 199, 306]. Strategies for overcoming these challenges include involving the audience actively in lectures through audience response technology (e.g. clickers [222, 250]), the use of active learning techniques (e.g. think-pair-share [210] and content based questions [139]), or even banning the use of personal computers in the lecture hall [367]. At the same timer distance- and online learning, e.g. virtual classrooms, e-learning, and massive open online courses, are becoming a potential competitor to the traditional university lecture [177, 370] (see discussion by [124]).

We do not believe that the traditional university lecture is going to disappear anytime soon, nor is the use of slideware and personal computers in the lecturing hall. Despite criticisms, existing facilities, student numbers and university economics are all arguments in favor of the university lecture. While the direct benefits might be contested, slideware seem to have a wide uptake in practice, as they support lecture preparation and reuse, gives (some) structure to the lecture itself, are favored among students as visual aids and resources in preparations for exams [4, 311]. Popular textbooks often come bundled with lecture slides matching the topics and chapters of the book[1]. While research show that laptops and mobile technology is a primary source of in-class distractions, the perceived benefits (e.g. from note taking, peer-communication, looking up online resources, staying online etc.) seem to outweigh the drawbacks when students decide to bring their laptop into the lecturing hall. So if the current technologies and the university lecture are here to stay in some form or another, we find it crucial to investigate how we can better support active student participation and collaborative learning within traditional university lecture, using the technologies already present within the space and with respect to existing (idiosyncratic) practices.

This paper follows our general research interest in place-centric and co-located collaborative computing using interconnected personal computers. The modern university lecture is a prime example of *disconnected* co-located personal computing. The students and the lecturer are in the same room, engaged in the same activity, yet their activity on their personal computers are disconnected (even though they most likely are on the same local wireless network). In this paper we outline a design space for using both students' and lecturers' interconnected personal computers in university lectures for creating technical infrastructures to support co-located active learning. We base the design space on three positions on learning and computing and a review of related research on technology use in lectures and of existing lecture support systems. We present a proof-of-concept system, InPlenary, and a study of its use in four university lectures in-the-wild combined with a survey of the students' habits of personal computer use in lectures. The contribution of this work is the development of a design space based on insights from existing empirical *and* design work. Whereas existing work only consider the lecturing hall as context, we focus explicitly on what it means being co-located and

[1] For example [290], see http://www.id-book.com/

the role of the physical space and the digital counter-part – in design and implementation. In contrast to previous work, we aim at combining use of personal devices as means for active participation *and* as a concrete strategy for mitigating and addressing the challenges the very same devices represents as a source of parallel activities and distractions. Finally, we point attention towards the role slides play to students outside the lecturing hall after lectures, something that previously has had little attention in literature.

11.2 Background

Active Learning

In the last three decades, different approaches to teaching have emerged to mitigate some of the shortcomings of traditional lecturing, e.g. passive learning format, little student-lecturer interaction, difficulties in assessing student understanding etc. (see [96, 186]). Active learning takes inspiration from a broad spectrum of theoretical traditions; pragmatism, constructivism, activity theory etc., and it covers a broad range of approaches and learning techniques[2]. Michael [257] summarise an extended literature review and list the five common ideas in active learning: First, learning involves the active construction of knowledge by the learner and represents a turn from imparting knowledge to students actively engaging with the concepts in order to develop a personal understanding. Second, learning facts and learning to do something are two different processes. Learning how to use knowledge towards problem solving requires opportunities for students to practice and receive feedback. Third, when learning some concepts are more domain specific than others (our course), and some are more readily transferred across topics and courses. Fourth, individuals are more likely to learn more when they learn with others. Learning is a social activity and talking to peers, asking and answering questions, summarising, discussing etc. are important aspects of learning. Five, meaningful learning is facilitated by *articulating* explanations to oneself, peers and teachers. Explicating and externalising concepts are crucial in learning and it provides opportunities for individual reflections and others to give feedback.

Studies of active learning research [131, 257, 291] and self-reported studies of using active learning techniques (e.g. [102, 123, 176]) report a positive impact from multiple disciplines on grading and performance, conceptual understanding and even increased attendance and active participation. Thus, there is clear evidence of the benefits of active learning and many research universities embrace educational change in this direction [342, 358]. This is often combined with digital learning designs to embrace the potential of technology in higher education [43]. A majority of the literature examine active learning techniques and many of the systems we have reviewed use active learning or

[2] See [257, table 1] for a broader overview the different approaches.

related concepts in the design. We build on this tradition to explore how students' ubiquitous personal devices can be used as a resource in active learning in the lecturing hall.

Place and technology

The first technology 'developed' to support lecturing in front of a large audience is the lecturing hall itself. The arrangement of the seats in rows, small desks, and a center stage with blackboard or projector screen, give strong indication toward the activities the space is intended to support. Understanding the lecture as a design space necessitates understanding the relationship between the physical properties of the lecture hall and its meaningfulness as a place embedded within a particular institution and practice. Giery [140] attempt to correct reductionist conception of place (as context or frame) and outline *place* as an entangled combination of location, physical material form and meaningfulness. The physical setting matters, not only in constraining and supporting specific activities but also as the result of previous activities, as crystallised knowledge (what Bærentensen & Trettvik [12] call cultural-historical affordances). Places are an important component in how we interact and socialise as individuals. Paulsen [283] talk about *place character* as a combination of *what* constitutes a place and *how* it matters culturally and in ongoing activities.

Place and space is a familiar perspective in human-computer interaction as a design space or object of design (e.g. [109, 193, 253, 256, 365]). Messeter have developed the notion of place-specific computing *"[...] as computing in which the designed functionality of systems and services, as well as information provided by these systems and services, are inherently grounded in and emanating from the social and cultural practices of a particular place, and account for the structuring conditions of place – social and cultural as well as material."* [256, p.32]. Without drawing on their work, Messeter positions place-specific computing very close to the theoretical and empirical positions of Gieryn and Paulsen. Kaptelinin & Bannon present technology enhanced activities as the object of design that encompasses *"[...] spatially and temporally organised configuration of resources, including digital technologies, which enable an individual or a group to carry out one activity or several coordinated activities."*[193, p.294]. Both positions suggest that 'supporting' implies a strong integration with the physical space and the activities it is already supporting; activities which have already given a specific place meaning and character.

Common information spaces and artifacts

Lecturing and learning encompass multiple artifacts and information resources. They each play a role within the activity. An important point in active learning is actively constructing concepts and knowledge as a social activity that requires articulation and externalisation. The role these resources (textbooks, disciplinary knowledge, examples, assignments, notes etc.) and technologies play is also recognised as an important part of activities within a given place. Being co-located matters and taking active part in the activity requires access to and is mediated by multiple information artifices and technologies. Lecturing can be described as constructing a *common information space*. A common information space *"[...] encompasses artifacts that are accessible to a cooperative ensemble* ***as well as*** *the meaning attributed to these artifacts by the actors."*[314, p.28]. It is negotiated and established by the actors involved in the activity, and Bossen point out that a common information space *"[...] should be regarded as the result of ongoing processes of achieving mutual interpretations of single items of information [...]"*[66, p.177]. They are open and malleable as working material for participants in a concrete activity, and they have closure and immutable aspects allowing travel across contexts and practices [21]. Robinson's [298] notion of *common artifacts* helps investigate the aspects of common everyday artifacts and the role they play in everyday activities. Just as common information spaces exhibit both plasticity and immutability, common artifacts allow complex implicit communication through and around them, they become "shared material" in the situation and mediate activities across contexts.

Here we focus on the role the common information artifacts play within the lecture as part of the information space that is developed and unpacked in common throughout the course wherein the lecture is one of several. The slides, notes, comments and activities thrive on the malleability within the situation. They are not fixed, but play a role in the co-located mutual interpretation and process of knowledge construction. If successful as common information artifacts, the outcome from the lecture should be materials, information artifacts and mutual interpretations that are useful and meaningful for the participants in their subsequent activities.

11.3 Related work

The use of IT in classrooms and lecture halls

There has been numerous studies of the introduction of slideware and information technology into lecture halls and its effect on teaching and learning. Studies on slideware tend to focus on the effectiveness of using PowerPoint in lectures; text versus multimedia, presentation style and the particular cognitive style impose on lecturing by tools originating from a commercial context. Although literature report that students prefer PowerPoint and believe it improves their academic performance, this is not always the case [5, 334]. Several studies on the effectiveness of PowerPoint are inconclusive. Savoy et al. [311] did not find any indication of better academic performance. As Amara [5] point out, multiple studies compare PowerPoint with overhead transparencies, and not traditional 'chalk-and-talk'. In a small self-conducted study, she find that traditional lectures result in better academic performance. Results reported by Szabo & Hastings [334] and Bartsch & Cobern [31] indicate that PowerPoint is better than overhead projected transparencies, in terms of recall and retention. Savoy [311] show that the use of PowerPoint has a negative impact on information retainment of what is being said, echoing Adam's critique of the role of PowerPoint in higher education:*"If it isn't on the PowerPoint, it probably isn't important"* [4, p.389]. Marsh & Sink [245] found that access to printed hand-outs during the lecture had some positive effects on recall and in a small study comparing three methods of delivering lectures (PowerPoint, chalk-and-talk and tablet based) Lumkes [233] report that students found lecture notes and handouts valuable when preparing for exams.

Another strand of empirical research follow the proliferation of personal computing and the impact this has on study habits, multitasking and learning. Although students use their laptops in a lot of relevant activities, e.g. note taking and assignments, the devices are both a source of distraction and used for parallel activities, e.g. web surfing, texting, social media, gaming etc., as reported by several studies [30, 173, 188–190, 199, 212, 306, 309]. Barkhus note that the use of laptops among the students are very polarising and used *"either to assist the student to follow the class, or to engage in a task unrelated to the class."* [30, p.143], Junco suggests that technology primarily used for social purpose (e.g. texting and social media) have a more severe impact on performance, than technologies that are used for academic related activities (e.g. email and browsing). Regardless of purpose Junco have found that the use of texting, social media and other forms of multitasking introduced into the lecture hall has a negative effect on academic performance [189]. In an experimental study Sana et al. confirmed that multitasking impairs learning and further showed that *"[...] comprehension was impaired for participants who were seated in view of peers engaged in multitasking."* [309, p.29].

Researchers have looked at how existing feedback and audience response systems, known as clickers, are used and can impact teaching in higher education. These systems often consist of either a dedicated devices that communicates with infrastructure in the room and/or a device attached to the system running the presentation (see [25] for an overview), more recent web- and smartphone-based applications that is integrated into or run independently of the specific presentation[3]. These systems allow students to respond to questions and tasks posed by the lecturer, often limited to responding with a simple keypad. Although Mayer et al. [250] and Yourstone et al.[369] found that embedding clicker based questions improve academic performance, research tend to focus on the immediate benefits of student and instructor feedback and the ability to pose questions to a large audience and allowing everyone to participate. Participating with clickers mitigate some of the social implications associated with speaking up in class (e.g. embarrassment, breaking the silence, publicly exposure). When looking beyond measurable impact on academic performance, research have reported a positive influence in student participation, sustained attention and increased attendance [82, 222, 339]. Beekes [33] report that using clickers anonymously can increase student confidence to participate

[3] E.g. webclicker.org or www.gosoapbox.com

more widely in class, which might challenge using clickers as more formal methods for student evaluation and grading. In a review of available commercial technologies, Barber & Njus [25] ask for more intelligent design. The current solutions are a mix of trade-offs (dedicated device/infrastructure, integration with slideware, consistency etc.) and are quickly outmoded. Moreover, dedicated devices are hard to upgrade, require maintenance, and difficult to expand their functionalities. Recently, vendors are developing applications for smartphones and browser based solutions are emerging, which are more promising in terms of avoiding dedicated devices (that students forget to return) and potentially allow better extendability and improved input methods.

Classroom and lecture support systems

Numerous systems have been developed to support lecturing and learning activities. Some of the systems are complete infrastructures developed with a focus on making the lecture more interactive and/or involving novel technologies that support specific activities, while others are more light-weight add-ons to existing components. We have focused on systems specifically developed to support the lecture within the lecture hall and systems involving some degree of active participation or presentation spanning multiple devices.

A few systems focus on supporting simple feedback and interactivity in lectures. ClassTalk [113] uses dedicated devices and infrastructure to support individual and group response to simple questions initiated by the lecturer. ClassTalk contains a management interface where the lecturer can identify each student and get (unspecified) information based on login and seating. ActiveClass [30, 340] is similar and allow lecturers to conduct polls and students to rate the progress of a lecture. Students can ask open questions through the system and vote for good questions posed by others. It is a web-based system and contains a control interface that allow the lecturer moderate and remove questions, and ‘spy’ on individual students. It is also possible to move selected questions to a forum where students can access these outside class. Initially students interacted with ActiveClass via PDAs, and later with their personal devices. ClassCommons [112] is a simple system where students can comment and discuss during the lecture. Comments are posted from their personal devices (or stationary computers within the lecturing hall). The comments are visible on a public display situated below the main projector screen. A comment is added with the student name as a way of introducing accountability. This social curation is the only form of moderation in ClassCommons.

Anderson and colleagues have developed Classroom Presenter over multiple iterations [6–8, 231, 361]. The first iteration, Classroom Feedback System, incorporated having student and lecturer views of a slide based presentation. Students can add simple feedback color markers to individual slides and the lecturer can return and address these if needed [8]. The second iteration, Classroom Presenter, focus primarily on annotating slides with ‘digital ink’ overlays [6]. This allow the lecturer to annotate slides with drawings using a dedicated tablet. The slides are synchronised via network and in later publications they show different examples on how lecturers use the system to answer student questions by adding extra explanations [231]. A third iteration focuses on allowing students to add annotations to slides and they send these to the lecturer, who then incorporates these into the lecture [7]. In the fourth iteration, Ubiquitous Presenter, the platform is re-implemented as a browser-based application to overcome the limitations in the previous standalone version. This allow students their own devices and access the slides and review feedback and submissions made by other students anonymously [361].

Intelligent Classroom [363] and Smart Classroom [368] are both systems that aim at orchestrating and connecting multiple devices within the learning space. Intelligent Classroom allow lecturers to use multiple platforms, e.g. presentation, video, audio, smart boards, and include these in the presentation. In Intelligent Classroom the multiple sources can be combined and made accessible to students via a web-based component for later review. Smart Classroom aims at connecting stationary computers with portable devices. This system support synchronisation of documents, assignments, calendar appointments etc., across the devices. It focuses on both student-lecturer and student-student communication.

UniPad [213] and a multi-table system developed by Martinez-Maldonado et al. [247] both focus on supporting specific well-thought out learning activities across multiple devices (tablets, smartphones, interactive tables and projectors) and classroom orchestration. UniPad allow students to explore and work on specific assignments in groups using shared tablets and the lecturer controls the progression with a dedicated orchestration application. In the system developed by Martinez-Maldonado et al. students work on interactive tables and the lecturer orchestrates the activity through a dedicated application.

The systems above represent different genres, from audience response systems to systems that are designed to support particular learning activities. The level of integration, supported devices and technical requirements varies. Some are dedicated systems encompassing the entire activity (e.g. ClassTalk and UniPad), while others are add-ons that support limited activities and participation (e.g. ClassCommons and ActiveClass).

11.4 Design Space

In the following we will describe six dimensions of a design space for systems for co-located active learning: *physical and digital space, communication and participation, orchestration and control, learning activities, materials and resources* and *integration with existing practices.*

Physical and digital space

In the lecturing hall participation is demarcated by the door, and activities such as verbal communication unrelated to the lecture is not tolerated as it obstructs the main activity. However, in the digital space there are no such spatial demarcations and outside activities tend to bleed into the digital space of the lecture hall. Multitasking on personal computers in the lecture hall is known to have a negative impact on nearby peers [309], however the opposite, creating highly visible use of the digital space as part of lecturing might have a positive impact. For instance, UniPad uses shared displays and 'looking over the shoulder' as a design objective to promote better learning.

The level of integration into the digital and physical space follow a continuum. Traditional lecturing happens only in the physical space and even with slideware there is no digital components that incorporate the participants and their devices except for the projector display on the wall. Distance learning is at the other end of the continuum, as it is place agnostic and done primarily through online platforms. Most of the reviewed systems fall somewhere in between. ClassTalk and ActiveClass support roughly the same activities, yet ClassTalk uses dedicated technology installed within the lecturing hall, whereas ActiveClass uses a web-based application that allow communication in parallel to the lecture itself. The degree of integration might also affect participation and the ability to integrate the activity itself. The activities of the digital space can be controlled in various ways. The extreme is to forbid all activity by banning personal devices or restricting network access. Another alternative is to block or somehow hamper access to certain online activities. Another more constructive approach is to provide means for participation in the lecture in the digital space as we explore in InPlenary below.

Communication and participation

Active participation require some form of communication and how systems support this influence the activities it may support and who gets to participate, when and how? A system can support *student-to-student*, *student-to-lecturer* and/or *lecturer-to-student* communication, and it can be continuous, periodic and/or focused as part of specific activities. Continuous communication offer multiple possibilities for participating, e.g. in a discussion or by asking questions, while shorter focused instances offer a lower 'bandwidth' for participation. There is a difference between continuous discussion and using a clicker with a numeric keypad to answer a multiple-choice question. The visibility of the communication influences participation. Ephemeral, student-to-lecturer or less visible communication (in a dedicated application) is easier missed or ignored opposed to highly visible and public communication.

ClassCommons and ActiveClass allow continuous feedback and questions among both students and lecturer, Classroom Presenter and ClassTalk focused and periodic communication from student to lecturer, and Intelligent Classroom and traditional presentation slides only support lecturer-student communication. Several levels of anonymity also influences communication and participation. In ClassCommons the comments were added with the students name to increase accountability. In ClassTalk and ActiveClass studens appear anonymous, but lecturers can see who posted what. Clickers and Classroom Feedback system allow completely anonymous use to lower the barrier for participation. Beekes [33] discuss how anonymity can help overcome shyness associated with speaking up in class and increase overall participation, at the cost of using the system to do more formal evaluation.

Orchestration and control

A larger topic in literature is classroom management and control. In some systems orchestration means the ability to use and control multiple devices as part of the activity and in others it is a matter of controlling the progress of the activity and input made by participants. UniPad and Multi-tabletop specifically focus on integrating control into the system itself and allowing the lecturer to control the progress of the activity. Intelligent Classroom is designed for more seamless integration and here orchestration is a matter of presenting across multiple platforms.

A few systems contain more implicit forms of control. ActiveClass contains a spy interface where a lecturer can observe and moderate contributions from the class and systems that offer fixed designed activities or utilised standalone hardware or software also introduces an element of control and orchestration. If students are required to use a specific application or device, how they interact with and contribute is easier controlled and/or orchestrate. Classroom Presenter introduces an interesting way of orchestration contributions from students. Students send their annotations to the lecturer, who then publish these to the class. In ClassCommons, the developers hoped identification might create accountability and (self) moderation. This did not work as intended resulting in spam comments.

Learning activities

The tenet of active learning is giving students opportunities for participating in and working with the subject matter. The techniques vary from the simple quiz-like activities to more complex think-pair-share exercises. Each of these require different capabilities of the system and considerations toward learning goals and expected outcome. Audience response systems and clickers tend to support simple activities and offer easy and resource efficient means of activating students. Although the students get a chance to contribute and compare their own answer to that of their peers, the simplicity of the activity affects is transferred over to the feedback. In contrast, Classroom Presenter support a different more material forms of activity with the annotation of slides and ‘digital ink’, and UniPad is constructed to support extended collaborative learning activities supervised by a teacher. Full support of specific exercises, like the financing training application in UniPad, requires a very particular and close integration within the system and preparation, whereas the more light-weight activities typically requires formulating a few questions and answer options.

Some of the systems support activities that are part of the learning process but not necessarily crucial to the lecture. ActiveClass allow students to pose and vote on questions before and during class and Intelligent Classroom make the lecture available for later review. These activities may not be part of explicit learning goals, but offer a broader support of studying and learning. Individual annotations on slides and note taking applications are examples of applications supporting more individual practices.

Materials and resources

The activity a system support include the materials and resources made available for the lecture and participants. Most of the reviewed systems make specific functions available exclusively in the lecture situation, e.g. ClassCommons and Classroom Feedback, and others make functions and information accessible before (ActiveClass) and afterwards. In the presentation of ClassTalk it is mentioned that the system persist everything, but it is not discussed what for. It is important to consider how materials developed within the lecture might support activities outside the lecture hall. Could the digital annotations be made available for review afterwards or can students get a script of the feedback. Is the material sharable or does the feedback only concern the lecturer.

ClassCommons depart from an idea of community and commonality, but the feedback and comments are ephemeral. It is considered common to the room and it is not considered if a particular comment might play a more lasting role in discussions or as an important question for further lectures. ActiveClass seem to offer such capabilities in the form of a developing a shared repository of questions, by moving particular questions to a different platform. If learning is a social activity and given the importance of externalisations in active learning, it becomes important to consider how systems can support such externalisations and make these available as a common resource throughout the lecture and afterwards.

Integration with existing practice

Systems for supporting lecturing can integrate with the already existing tools, supplement them, or directly replace them. Software for clickers allow integrating results of a poll directly in commercial slideware like PowerPoint or Keynote, while other systems e.g. ActiveClass and Smart Classroom, exists in parallel to the slideware system. UniPad and multi-table replace slideware and requires a complex setup, while Intelligent Classroom augment the traditional slideware systems by integrating multiple presentation tools Activities like note taking can be supported explicitly (through dedicated note taking tools) or integrate with existing practices by allowing for (shared) file storage, hereby allowing for the use of different kinds of software for note taking. On a hardware side systems can either provide custom hardware (e.g. clickers), loaned devices (e.g. a class set of laptops or tablets) or exploit the personal devices of the students (and lecturers). For the personal devices software can be app-based (potentially more expressivity but platform dependent) or web-based (some limitations on features, e.g. sensors, filesystem etc., but platform independence). We believe the level of integration is an important parameter both impacting degree of participation, and also potentially impacting the level of distraction.

11.5 InPlenary

To explore the above design space and to demonstrate consequences and potentials of design choices, we designed implemented and studied a system we have dubbed *InPlenary.* InPlenary is built on a number of design principles drawn from the above design space.

Physical space as a first class digital entity and the scope for participation. We want to give precedence to physical proximity and make digital activities visible within the space. In InPlenary physical presence is a requirement for participation and subsequent access to the information produced as part of the activity. Participation in InPlenary is anonymous, but physical co-location should act as social moderation.

Focus on learning activities by integrating pedagogical exercises based on active learning principles and use students personal devices as an important entry-point for participating in the lecture activities. By activating the personal devices as part of the primary activities we want to encourage active participation and avoid or downplay multi-tasking and parallel activities.

Integrate with existing practices to support broad participation, both from the perspective of the lecturer and the students. Using the system should add something extra to the lecture, without taking something away from traditional lecturing and existing use of slides. This also implies supporting as many personal devices as possible to avoid exclusion by incompatibility.

Focus on the commonness of co-located lecturing and learning. This means supporting the process of building a mutual understanding within the lecture and see the slides and the information generated in the lecturing activities as a common reference and resources, but during the lecture.

Design

The design of InPlenary focus on supporting the lecturing situation itself, and secondary preparing lecture slides and access to the these and activity information afterwards. Lecturers prepare their slides in another application of choice and export these for upload into InPlenary. InPlenary contains a simple editor that support adding slides, lecture notes and activity slides containing different leaning activities. We distinguish between

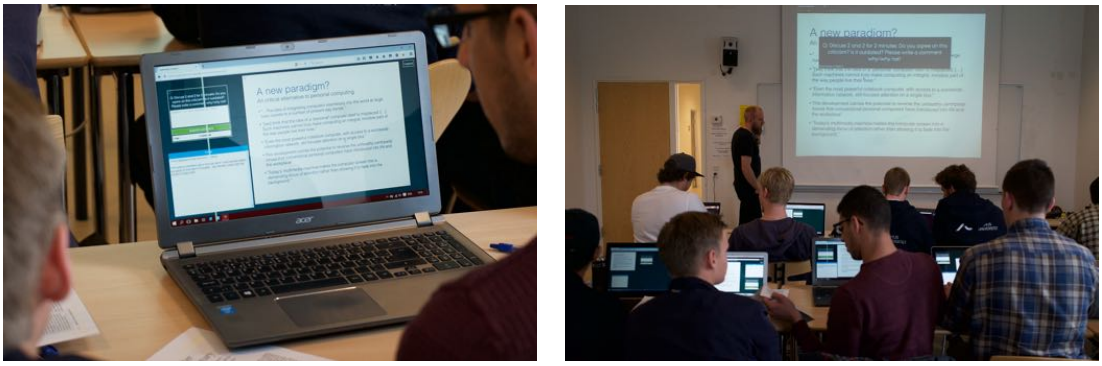

Figure 11.1: Left: Student view: Discussion & notes. Right: Projector view: Discussion slide

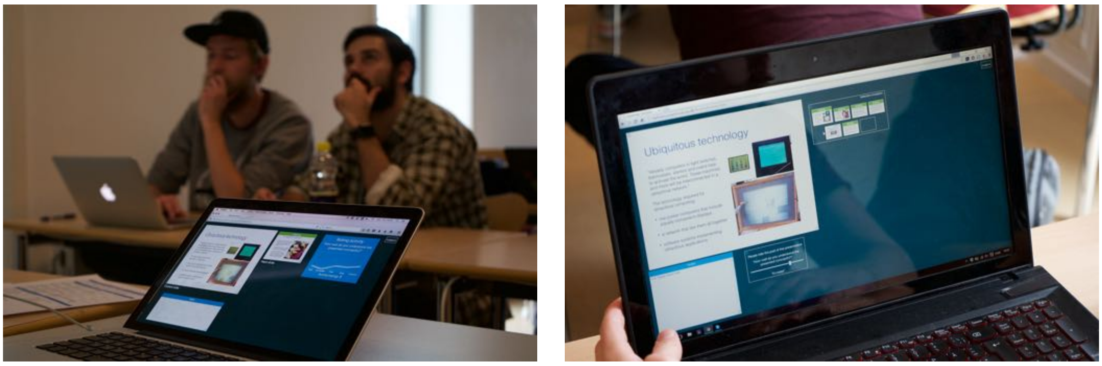

Figure 11.2: Left: Lecturer view: Slides & Rating Right: Student view: Reflection & Rating

slideshows and lectures in the system: Slideshows are based on the uploaded slides and is the primary working object of the lecturer. Edits and additions are made to the slideshow in the editor. Lectures are instantiated slideshows, meaning that once a lecture is initiated, a lecture is created based on a particular the slideshow. This allow reuse and development of slideshows without changing the slides presented at a specific lectures. Thus the lecture slides are what is shared and further enriched throughout the lecture.

Another important distinction is the difference between being in the lecturing hall and then outside activities. It is not possible to start a lecture without being in the lecturing hall and access to the lecture slides afterwards depends on having been present during the lecture. Once initiated within the lecturing hall, the lecture slides are visible on multiple devices with their own specific views: A lecturer view, projector view and audience view (Figure 11.1 and 11.2). Each view show the current slide, and when activity slides are active, a specific interface for the learning activity. Additionally, the audience and lecturer view has a notes area, and the lecturer can see the upcoming slide and control the presentation. When a slide is changed it changes across the views correspondingly. To access the presentation, the device needs to be logged into the system via a specific Wireless Access Point in the lecture hall. The access point couples the participants to the room and the lecture slides and make it possible to participate in the embedded activities and access the slides afterwards.

InPlenary has five different activity slides which can be added to the slideshow in the editor. All the slides are added before the lecture and the results are integrated into the lecture slides and accessible afterwards. They appear when reaching the slide upon which they are added. The aggregated results from an activity is available to everyone who participated in the lecture (via the access point) and participants can see their personal response, if any.

Poll. The poll slide enables the lecturer to conduct a poll. The activity consists of a statement and/or question with up to six response options. The poll question is visible on the slide and students can vote through the student interface. The lecturer decide when to display the results and whether or not the voting is public.

Clicker. The clicker slide allows the lecturer to conduct multiple choice questions. The clicker slide is similar to the poll slide in design, with the only exception that one of the voting options is flagged as the correct answer.

Discuss. The discuss slide allows the lecturer to initiate a discussion based in an statement and/or question. The students then respond either individually or in pairs by posting an answer through their own interface. The students can see the responses made by others and vote these up or down. Once the lecturer is ready to continue, it is possible to display a subset of responses on the projector view. The lecturer can select the three highest or lowest voted, or pick any three from a list in the lecturer interface. This allow further discussions and juxtaposition of the student comments.

Rating The rating slide is added to an existing slide and extends the student interface with a slider widget where the students can rate how well they understood the contents of the slide. The results are displayed as a graph in the lecturer view and on projector view as a small overlay.

Reflection. The last activity slide supports student discussions and reflections. Based on a statement and/or question and a selected subset of the slideshow, the students can navigate this subset of slides freely while they discuss and reflect on the statement. This can be done in smaller groups, pairs or alone, depending on the lecturers design of the exercise. The students control the slides on their computer, while the activity slide is still displayed on the projector. If any of the slides in the selected subset is a rating slide, the students can change their rating. The changes in ratings are reflected on the projector with a red/green color overlay.

Course	Duration	Participants	Users users	Survey responses	Interviews	Rating		Poll		Clicker		Discuss			Reflection
						N	Avg. rating count	N	Votes	N	Votes	N	Comments	Votes	
Adv. Interaction Design	1h 45min	35	26	28	4	6	10.3	-	-	1	24	1	14	72	1
Organisational analysis	2h	43	34	26	2	4	17	-	-	2	28/28	2	21/16	100/48	1
Software Architecture[1]	1h 30min	9	7	9	2	11	6.4	-	-	1	6	2	7/5	14/14	2
Open talk on Ubi. Computing[1]	45min	15	13	15	5	5	10.6	1	13	1	10	2	8/8	11/49	1

Figure 11.3: Study overview: Number of participants in the study and used activity slides with interaction data.

Implementation

InPlenary is consist of three components: A web-based frontend implemented in HTML and JavaScript, a server handling slides and client serving lecture slides implemented in PHP, and an network infrastructure that is used as an access point to the application and handles the coupling between users and lecture presentation. The management interface where slideshows are uploaded, edited and initiated are part of the web frontend. The implementation draws on the existing university authentication infrastructure to avoid additional configuration and client registration.

The lecture hall setup consist of one or more wireless access points that exposes a InPlenary SSID containing the room number, e.g. InPlenary Room 1. Once clients are connected and point their browser to a dedicated address (e.g. inplenary.some-university.edu), they will be coupled with the given room and the lecture once initiated. The projector within the room is connected to a computer dedicated to the lecture hall. A lecturer has permissions to initiate a lecture within a lecture hall. Starting a lecture loads the prepared lecture with slides and activities on the student' clients and the projector client. When the lecturer changes slides through the lecturer interface the current slide on all other clients will automatically update.

Activity slides have three different interfaces; one for the students, one for the lecturer and one for the projector. Students' interactions will be posted to the server, persisted, and distributed to the other clients (e.g. to live update the overall result graph of a rating slide). Activity slides are implemented self contained web-apps, which means that it is easy to extend InPlenary with new activity slides in the future. The student interface allows basic customization of appearance, and contains a personal note field where entered notes will be persisted together with a given ongoing lecture. Once the lecturer ends the lecture, the lecture object is finalised and made available for further review. Students can access finished lectures from the InPlenary website if they were present in the lecture hall when the lecture was ongoing.

11.6 Study

We tested the system in four lectures in order to explore the potential and implications of our particular design. We wanted to investigate how well it supported the lecturing situation as a whole, the distribution of interfaces and functions, and how students and lecturers experienced the learning activities. We recruited two colleagues for two of the lectures and two of the authors conducted the other two[1] (see table 11.3). One of the lectures were an invited lecture where students was asked to participate outside their normal study program. This allowed us to focus more in depth on the use, capture video of the users with their permission, to pause and focus on particular aspects throughout the lecture.

Prior to the lecture we asked the given lecturer to prepare their lecture as normal. Following that, we did a session where we introduced the system and assisted in adding the different learning activities to their slides in the system. During each of the lectures at least one of the authors participated as an observant and technical aid in case of a breakdown. Before beginning the actual lecture, we did a short introduction of the system to the students. This enabled us to handle initial technical and usability issues, answer questions and allow the students to try the learning activities before the actual lecture. For each lecture the students where asked to fill out a questionnaire (N=77) on their general use of technology in their studies, their note taking practices and use of lecture slides[4]. The purpose of the survey was to get detailed information about their use of technology and to position the participants in relation to findings in the literature. After the lecture we recruited students for an short interview on their impressions of the system and use of lecture slides in general (N=11). We also interviewed the two recruited lecturers. All of the interviews were semi-structured and we used the system to go through the particular lecture and the results from the learning activities. The interviews have subsequently been transcribed and analysed through meaning condensation [219].

11.7 Results

In the following we report the findings from the our study, using the data from the survey, interviews, observations and analysis of the data from the learning activities.

Basic use of InPlenary

Each of the lectures used one or more of each activity slides, except from the poll activity that was only implemented for the last lecture. Table 11.3 show an overview of the lectures and the activities embedded in the slideshows. The lectures progressed without major breakdowns and using InPlenary did not seem to obstruct the lectures significantly. Getting started (connecting to the network instead of the projector) cause some initial delay and students reported having to get used to having the slides on their own device and interacting with the system. The lecturers used InPlenary as they would have used any other slideware and we observed how they quickly forgot about the system in the parts of the presentation with normal slides. We did not get any reports

[4] We tested the survey beforehand with non-participating students.

in relation to usability of the application throughout the lecture, afterwards or in the interviews; everyone seemed please with the general design. In the interviews several mentioned having the slides on their own device as useful: it helped focus on the lecture; made it easier to keep up with the lecture and read slides. Two respondents said it took some time to get used to and one preferred if all the interfaces (the projector and his student view) was identical. In all of the lectures the students did take advantage of the ability to organise the workspace on their own screen (see figure 11.1 left and 11.2 right). Initial use of the system did result in some playful interactions and explorations of the functions. In the lectures involving more than 20 devices used simultaneously we experienced a few issues with students not being able to access the slides in small intervals. This did not have a significant impact on the ability to participate. The slides were still visible on the main projector and participation in the activities could easily be done in smaller groups, and several of the learning activities was designed for that (e.g. discussion and reflection).

Interaction and participation

Data from the system and our observations show that students frequently interacted with the system throughout the lectures. The respondents found it easy to interact with the system and saw the activity slides as a welcome alternative to speaking up in lectures, which they all associated with some level of embarrassment or fear of being wrong. The respondents found that the level of anonymity made it easier to contribute in the activities and allowed them to answer more freely and even test ideas and their understanding in the comments. They found the high visibility of the outcome of the activities made it easier to use the results as an outset for subsequent discussions. One respondent noted that even when contributions were anonymous, the setting and visibility gave him a sense of accountability. Students found the clicker and poll activities simple and a useful way of getting quick feedback within the lecture. Although some questioned the usefulness in terms of addressing difficulties, a common reflection was that these light-weight activities were a useful tool for lectures to assess the level of understanding and progression of the class.

The respondents were very positive toward the discussion and reflection activities. Students found that contributing with smaller inputs as part of the discussion activity was an opportunity for contributing with little direct consequence. The ability to vote contributions up and down was also seen as beneficial toward a following discussion. This allowed a more detailed examination of why and how different statements were useful. In all the instances, the comments made through the system played a role in the subsequent discussion and the lecturers compared and commented on selected comments. During use of the reflection activity we observed students using it continuously as part of the embedded exercise. The ability to review a subset of the slideshow was seen as useful and several found that it forced them to relate to and compare concepts on the individual slides more consistently than when just asked to discuss presented concepts. The ability to navigate (back) and review previous slides was suggested as a permanent feature by half of the respondents.

The rating activity was generally experienced as confusing and the real-time updates on the main projector were found distracting. Students said that they did not know what they were rating: the presentation, their own understanding, information, complexity and/or progression rate. They did not find the feature particularly useful and in all the lectures the ability to affect the visible rating curve, prompted students to play with the interface, rather than contributing. The lecturers found it hard to react upon. Given a low rating should they pause and act upon it or use it at a later point for evaluating elements of their lecture? Several students responded that they found the activity slides a welcome pause for reflection and making lectures more dynamic. As one participant noted *"It's nice way to shake things up and avoid zoning out or falling asleep".*

Contribution and quality

Students and lecturers all agreed that using the system resulted in a significantly higher amount of input and contributions compared with simply posing a question to class. As seen in table 11.3, a majority of the students participated in the activities. The clicker and discuss activities prompted more participation than the rating activity. When going through the comments from the discuss activities we found that the students up-voted comments and contributions that we assess as more precise or relevant than those down-votes to the bottom. We only found witty and irrelevant comments when introducing the system, and even then students down-voted the comments. In all the lectures the lecturer reviewed and commented on the contributions. When reflecting on the contributions, the interview respondents emphasised quantity and visibility as positive things. They found it supporting subsequent discussions and beneficial to see what others thought on a particular question and read their responses before discussing in plenum.

The interviewees did see the discussion activity where they primarily contributed. Answering a multiple choice question or poll is seen as an easy way of participating and not as contributing to the lecture in the same way. Although they found it interesting to see if one answered a question correctly, they characterised it as a more light-weight activity and dependent on the question.

Potential Use outside the lecturing hall

Links to the lectures captured within the system were shared with the students, but we did not request or investigate subsequent use. In the follow-up interviews we asked about the usefulness of the information gathered as part of the learning activities and the requirement of participating in the lecture in order to have access the the richer lecture slides afterward. All the students we interviewed expressed that they would find the added information from the learning activities useful when preparing for the exam. They reflected that the information would be useful for focusing their preparation, identifying weaknesses, e.g. through reviewing their clicker responses and ratings, and use the comments from the discussion as examples. Several noted that if they had answered a question wrong or misunderstood something in the lecturing situation, where the literature and concepts was most present, they should properly focus on those concepts and instances when reading for exams. In contrast to their in-lecture experiences with the rating activity, it was seen as an important element in getting an overview over the difficult elements. Here they emphasised gaining an overview over multiple presentations based on their personal rating, and not the aggregated rating.

The respondents reacted positively toward the idea of basing access on attendance, but quickly imagined situations where it would be unfair, e.g. sickness and emergencies. On one hand they welcomed 'rewarding' or giving incentives for participation, on the other hand several raised concerns related to excluding students unable to attend for valid reasons.

Existing use of technology and lecture slides

In the survey, half of the students reported using more than one device in their studies. A single student identified pen and paper as the primary tool, a few used tablets, but the majority (95%) identified their laptop as the primary device. This correspond to what Junco report [190] and indicates a very broad use of laptops and mobile devices. The respondents use their devices for reading, assignments, note taking, texting, browsing, email and social media. From our in-class observations, we saw that students primarily had their laptops on the desk in front of them, while smartphones and tablets was tucked away. We did observe examples of students using their smartphone to take pictures of the presentation and one interviewee told us that she often used her tablet to take pictures to supplement her notes. When asked for their texting, social media and browsing habits, a third said they only engaged in these activities during breaks and a third whenever they received a notification. Only a fifth reported frequently use throughout the lecture, while the remaining 12% said they never used these in class. Although we asked differently (frequency, during breaks and on notifications), the frequency reported is higher than reported by Junco [189, table 1.]. Our observations indicate diverse multitasking practices and we saw everything from browsing, social media, gaming, watching video and what seemed like course work for a different class. When asked, 32% found these activities distracting and 57% did not. Although these findings are not primary to this research, they do indicate that the participants have similar practices as those reported in related work.

The survey and interviews confirmed our own experience related to the use of lecture slides throughout a course. If available, they review the slides beforehand (18%), view them during the lecture (32%), integrate slides with note taking (27%), as part of group work (64%) and for exam preparation (86%). When asked how frequently they downloaded the slides after lectures, 61% answered often or always. 93% replied that they download the slides when preparing for an exam. The interview respondents emphasised lecture slides as a resource within the course, similar to notes, assignments, examples and literature in relation to exams and working with subjects in the course. All but one interviewee used lecture slides as part of their preparation practice and lecture slides play an important role when preparing for an exam: they help building an overview and generating awareness toward the important aspects of a course; they help students plan and focus their reading; they indicate what the lecturer sees as important within the subject area and literature; and they are a source of examples and main points. One interviewee said he used them as a check-list to ensure he had read and covered the main topics of the course and another referred to lecture slides as an important 'preparation tool' for exams. Where existing work focus on particular lectures and the impact of slideware within that frame, our study indicates that slides play a larger role throughout a semester.

11.8 Limitations

The study and InPlenary served as a way of exploring some of the issues within literature and theoretical understandings of what role technology might play in university lectures as a design space. Our study and the insights feed into that work, rather than attempting to assess the impact on learning. Investigating the direct impact on lecturing and learning is difficult as we have seen in the related research on slideware. We do not think it is possible, as the introduction of a new system and the study thereof is simultaneously an exploration of the potential and a study of the multiple (and idiosyncratic) practices involved and how they change. If possible, such an endeavour requires a well-proven and broadly deployed system, and longitudinal studies across multiple courses. This is a limitation that seem to be prevalent within the research domain.

As always, testing a system that utilises a broad range of devices, network infrastructure and concurrent content delivery is bound to face technical issues. This can only be tested in an actual setup, as we are dependent on a large number of unique hardware clients (virtual devices would balance the traffic internally and never produce real conditions). In a room with multiple access points and a large number of hardware clients, radio interference, network hopping and other issues are bound to stress the network. This is partly an issue on the client device and partly an issue related to how the network is configured. This can be partially solved in configuration and optimisation on the network side, but that kind of use also requires some improvement on the client hardware side. This is the core technology based limitation in deploying and using the system we have faced.

11.9 Discussion

When entering a lecture hall or a classroom, students have some common understanding of how to behave and what is about to happen. In case they should have forgotten, the physical space give strong indications toward its purpose. In contrast, when seated and opening a laptop, the realm of possibilities are much more disconnected and detached from the primary activity. With InPlenary we have attempted to tackle this detachment by focusing on the physical space as the scope and outset for designing a digital system that supports co-located learning activities. We have in a very tangible way, attempted to activate the devices as part of the lecture by making the object of attention (slides, questions, activities etc.) highly visible on student' personal devices and by making the personal device an entry-point to participating in the learning activities throughout the lecture. Not only to the individual, but also to the ones seated nearby. The rationale behind these design choices are simple: If the students see and participate in the primary activity through their personal devices, the opportunities for and temptation to engage in parallel activities are less. We want to give devices a valuable and commonly recognisable role to play in the primary activity as a strategy for mitigating multi-tasking, interruptions and the temptations of social media, texting, gaming, browsing etc. The value of the system, as we propose it, lies in its ability to support active participation within the lecture *and* to utilise the capabilities of a system to capture data from the situation that is useful in subsequent activities. Instead of slides being a finalised product of the lecturers preparations, it a shared resource in the situation; a resource that is further expanded on and enriched in the process.

It might be controversial to use presence and participation within the lecture hall as a way of granting exclusive access to the content produced by the participants, as excluding those who do not find it necessary to attend a lecture. But the rationale is simple: The active process of developing a mutual understanding of the subject matter within the lecture should only concern those involved, and if the result of the situated activity is embedded in information artifacts, it *only* makes sense to those involved subsequently. Again, embedding these considerations into the design of these kinds of systems challenge the dominant conceptions of technology as being accessible to everyone, anywhere. It seems like the role of *local* area networks has been forgotten and reduced to global access to the Internet [204]. A development that is part of the problem-space, as global access also means global access to the attention of students. This should be a concern and consideration when designing systems that are meant to support something as complex and important as learning.

11.10 Conclusion

In this paper we have presented InPlenary as a system for co-located active learning in university lectures. The system is a particular exploration of a design space outlined through positions on active learning, place-centric computing and common information spaces, and a review of existing systems and studies of technology use in lecture halls from the research literature. Through the design of InPlenary, we have demonstrated one approach to use existing infrastructure and personal devices to distribute the lecture presentation across multiple devices, embed learning activities within the lecture, use personal devices as an entry-point for active participation, co-develop the lecture presentation as a common information artifact throughout the lecture, and coupling users to an information artifact based on connection to a wireless access point. Our findings indicate a potential in supporting co-located participation using personal devices and infrastructure that distribute not only the lecture presentation but also learning activities. Our findings on how technology is used within the lecture hall echo those reported by others and we expand on the discussion by pointing to the role lecture slides might play outside the lecture hall in subsequent use.

Chapter 12

Publication V: Proxemic Transitions: Designing Shape-Changing Furniture for Informal Meetings

Proxemic Transitions: Designing Shape-Changing Furniture for Informal Meetings*

Jens Emil Grønbæk, Henrik Korsgaard, Morten Birk,

Marianne Graves Petersen and Peter Gall Krogh

Abstract

Shape-changing interfaces is an emerging field in HCI that explores the qualities of physically dynamic artifacts. At furniture-scale such dynamic artifacts have the potential of changing the ways we collaborate and engage with spaces. Informed by theories of proxemics, empirical studies of informal meetings and design work with shape-changing furniture, we develop the notion of proxemic transitions. We present three design aspects of proxemic transitions: transition speed, stepwise reconfiguration, and situational flexibility. The design aspects focus on how to balance between physical and digital transformations in designing for proxemic transitions. Our contribution is three-fold: a) the notion of proxemic transitions, b) three design aspects to consider in designing for proxemic transitions, and c) a novel prototype of shape-changing furniture, which allows for gradual transitions between a table and a board surface. These contributions outline important aspects to consider when designing shape-changing furniture.

12.1 Introduction

This paper investigates how the theory of proxemics [162] might inform the design of shape-changing furniture with interactive surfaces. Shape-changing furniture opens up new possibilities in designing for dynamic social situations such as informal meetings. Interaction proxemics articulate how properties of interactive devices inherently serve to configure people in spatial ways with respect to the technology, content and each other [255, 272]. This paper investigates the hypothesis that shape-changing furniture offers new opportunities for interaction proxemics in the way that the ability to shift spatial

*This paper is accepted for CHI'2017. I have included the original submission, as we are currently revising the camera-ready version.

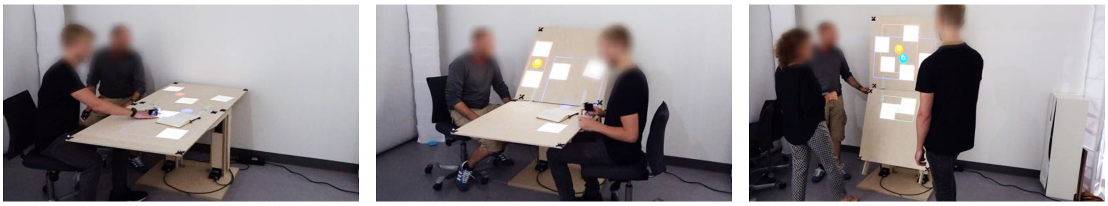

Figure 12.1: ProxemiSurface: Shape-changing furniture with interactive surfaces allowing people to change proxemics by gradually transitioning between tabletop and wall display configurations.

configurations accommodates for transitions in proxemics. As mentioned by Leithinger et al. [226], what is particularly interesting about shape-changing furniture is the spatial dynamics that they enable, and we particularly explore what these dynamics enable for informal workplace meetings.

Design of interactive, shared surfaces such as digital tabletops [315, 318, 359], wall displays [32, 147, 326, 338] and combinations hereof [354, 359, 362] is an active research area in exploring new ways of orchestrating collaboration through technologies. Studies have shown that vertical and horizontal surfaces have different properties in how they support collaborative activities [304]. Even though these shared surfaces hold unique properties in supporting group dynamics, they rarely accommodate for shifting physical constellations. Only recently, attention has been drawn to the opportunities for shape-changing surfaces to support collaboration [147, 335, 336]. Furthermore, recent work on shape-changing interfaces has started to explore the combination of physical shape change and digital animation, bringing attention to how properties of the two paradigms might complement each other [18, 129, 225, 230, 308].

We present the design of *ProxemiSurface*: a shape-changing surface that can transition between being an interactive table and a wall surface as well as taking a bended form in between. The design explores the qualities of having dynamic horizontal and vertical surfaces in supporting the multitude of ways people enact spatial relations during informal meetings. It further explores how user interface transformations and physical transformations complement each other in supporting interaction proxemics. With a Research-through-Design approach [216], the design work draws from theories on proxemics, and iterations between design explorations and empirical studies of a highly dynamic work environment. We analysed the interaction proxemics and dynamics of informal meetings in a real-world work environment to inform the design of dynamic furniture. Based on recurring scenarios of informal meetings, the form factor of ProxemiSurface was designed to enable a group of people to maintain shared space, while switching between the affordances of different vertical, horizontal, and in-between configurations around a shared surface.

The design explorations have led to defining the notion of *proxemic transitions* as a design concept for shape-changing furniture. Proxemic transitions has served as the conceptual glue [278] and nucleus of the research interest [216] in how it links together empirical and constructive solutions on dynamic furniture. The paper highlights three aspects of proxemic transitions – namely *transition speed*, *stepwise reconfiguration*, and *situational flexibility* – all three tying together the proxemics of informal meetings and the spatial qualities of ProxemiSurface.

In this way we contribute with the following: a) the concept of proxemic transitions for articulating a possible design space for shape-changing furniture in workplaces, b) an outline of three qualities to consider in such designs, and c) *ProxemiSurface* – a novel prototype of shape-changing furniture to envision and explore shape change in a workplace setting.

12.2 Related work

This paper relates to a substantial body of work that spans multiple areas of inquiry, including design of novel shape-changing interfaces, interactive surfaces, workplace studies and proxemics theory.

Shape-Changing Interfaces

Shape-changing interfaces is an interdisciplinary research field bringing together competences from design, art and computing in exploring the potential of physically dynamic artifacts [226, 292, 308]. Rasmussen et al. [292] has proposed a taxonomy for articulating the design space of shape-changing interfaces. The paper highlights key challenges for the field, including moving beyond point designs, and argues that future work within the field should use a systematic approach in exploring the design space by combining purpose with shapes and transformations [292]. Our work takes up this challenge in exploring design of furniture-scale shape-changing interfaces with the purpose of supporting informal meetings. A few examples of shape-changing furniture and room elements have emerged recently [158, 226, 335, 336]. In the work domain, the subjects of study have ranged from dynamics regarding ergonomics, privacy and variable group sizes [147, 226] to dynamic shapes in relation to task performance [335]. Only very few have explored how shape-changing interior can facilitate collaboration [335, 336].

Furthermore, a line of research in shape-changing interfaces explores the combination of physical shape change and digital animation using spatial augmented reality [18, 129, 225, 230, 308]. Common for this research is investigating how properties of physical transformation and pixel displays can complement each other. We build upon the work of Lindlbauer et al. [230] who compare virtual and physical transformation on a combined augmented reality and shape-changing tablet-sized object. The property *speed* is compared stating that physical transformations are limited in speed by the physical constraints of the actuators in the object, whereas pixel animations are only limited by the frame rate. Our work seeks to explore how this aspect of transformations (among others) compares in the two paradigms for supporting the dynamics of ad-hoc collaboration.

Interactive Surfaces and Spatial Configuration

Spatial properties of physically static interactive surfaces and their impact on collaboration have been widely studied in HCI. In particular tabletop and wall displays have formed the locus of attention, but also augmented furniture considered more widely [326]. Prototypes have illustrated how orientation [318] and territories [284, 315] can serve as means for coordinating. Scott et al. [315] found that when people collaborate around tabletops they organize in the interactive space in *personal*, *group* and *storage* territories. The concept of territoriality relates to Hall's notion of distance zones and personal space, and we also make use of these concepts and principles in the design of ProxemiSurface. In addition our investigation builds on studies of how the spatial configuration of displays matter. E.g. studies have illustrated how different physical display configuration in public space have implications for crowd sizes and social learning [338]. Rogers et al. [304] compare impact of vertically or horizontally oriented displays concluding overall that tabletop displays are good at supporting cohesive collaboration amongst groups of up to 3-4 people whereas wall displays are superior for changing group sizes and when dealing with information which is being primarily shown to participants. This work is highly motivational for our research and we contribute with investigating how dynamic surfaces can serve to enable these properties in an ad-hoc fashion during informal meetings.

Workplace Studies and Co-located Interaction

Multiple studies within computer-supported collaborative work (CSCW) have touched upon how spatial organisation and layout affect awareness and coordination, local mobility and co-located work practices [27, 39, 111, 232]. In the early work, stationary computers, screens and telephones forced workers to move between equipment, stations and rooms throughout their activities. Heath & Luff [232] introduced the term *ecological flexibility* to characterise how well artifacts and technology supported spatial adaptation. Whereas paper documents easily follow the work and affords sharing, reorientation, folding, annotation, etc., the stationary computers required work to be relocated. Today, mobile computing has increased the ecological flexibility to some degree, but other aspects of the physical environment still require people to adapt continuously throughout their activities. In a study on social dynamics and spatial work practices in open office spaces, Bjerrum & Aaløkke [46] found that ad-hoc collaboration and informal meetings played an important role in everyday knowledge sharing and collaboration. We have adopted their focus on informal meetings in this paper and made use of their notation in analyses of spatial dynamics. Birnholtz et al.'s [42] study on privacy and awareness in a similar environment show the importance of local mobility and proximity in coordination and awareness. Not surprisingly, workers used moving into proximity as a way of creating attention prior to initiating interaction, and as a way of judging whether the interaction would be convenient to others.

Proxemics and F-formations

Recently, Hall's theory of proxemics [162] has gained attention in the HCI community [16, 149] for his accounts of how people use space for enacting their social relations. Often proxemics is complemented with Kendon's theory of F-formations describing a range of spatial patterns in group formations [196]. These social theories provide together a useful language for understanding and designing for social situations involving co-located people and shared artifacts. Most related work on proxemics is inspired by the approach from Greenberg et al.'s concept of *proxemic interactions* in sensing proxemic distances and F-formations for sensing spatial relations as means for interaction [9, 16, 149, 243]. A different strand of attempts use proxemics and F-formations analytically in interaction design to derive broader implications for novel interaction paradigms [151, 246, 255, 319]. Mentis et al. [255] and Morrison et al. [261] provide findings regarding how physical properties of interactive artifacts have implications for how people can arrange for discussions and collaborations. These insights can be used to understand how some properties work well whereas others impede people's abilities to collaborate. These insights have driven our theoretical concept of proxemic transitions in supporting a flexibility towards physical properties of interactive artifacts.

12.3 Proxemic transitions

The theory of proxemics has inspired our vision for shape-changing furniture. The following section seeks to introduce the theoretical foundation for and define the concept of proxemic transitions.

Hall [162] distinguishes between fixed- and semifixed-feature space, where buildings are an instantiation of fixed-feature space, and furniture or other potentially movable artifacts are instances of semifixed-feature space [162]. Our vision for shape-changing furniture is inspired by Hall's descriptions of the relationship between semifixed-feature space and human behavior. He describes how certain features of a space either support or inhibit a certain type of social behaviour. Accounts from an experiment in a hospital define rooms that tend to keep people apart as *sociofugal* space and rooms that tend to bring people together as *sociopetal*. His conclusion describes the desire for spatial flexibility [162, p.110]:

> *"...sociofugal space is not necessarily bad, nor is sociopetal space universally good. What is desirable is flexibility and congruence between design and function so that there is a variety of spaces, and people can be involved or not, as the occasion and mood demand."*

Papers on interaction proxemics [255, 272] emphasize the need for considering proxemics in design of novel interactions. Mentis et al. [255] provide a great example of how the theories of proxemics and F-formations can come together and help articulate spatial properties of interaction designs and their social implications. In a study of collaborative practices in neurosurgery, they highlight three dimensions of proxemics that are important to consider in collaborations involving shared displays – namely *control proxemics, deixis proxemics* and *perceptual proxemics*. These accounts are in line with Hall's arguments about how features of a space either support or inhibit a certain type of social behaviour. Morrison et al. [261] highlight the role of F-formations and the ergonomics of horizontal and vertical formats in patient records in facilitating or hindering group use of patient records. Both studies show how physical setup of the technology may impede the ability to collaborate or have discussions.

Building on this work, our design explorations revolve around understanding how shape-changing furniture with dynamic horizontal and vertical displays might support proxemics and F-formations for collaboration. Our vision for shape-changing furniture is to provide a flexibility for reshaping shared space to suit a variety of situations. We envision that maintaining the same shared space, while being able to switch between the affordances of different spatial configurations on a shared artifact, will enable more flexibility and a variety of spaces for co-located collaboration. Through the design of ProxemiSurface, we explore the question of what it might bring to the interaction proxemics of informal meetings that displayed content can transition between hybrids of a horizontal and vertical surface.

In line with Mentis et al. [255] we found that people organize and negotiate space to optimize their proxemic relations regarding deixis, control and perception. However, the focus of this paper is on designing for *the act of organising and negotiating space* with dynamic furniture. To emphasize this focus we coin the term *proxemic transitions* to extend the conceptual framework of interaction proxemics. A proxemic transition is defined as an event involving at least two people negotiating a change in spatial arrangement, i.e., either arranging in a certain F-formation around content or spatially reconfiguring or reorganising artifacts in the surrounding environment. We distinguish between (1) *adapting*, i.e. adapting one's posture or position in relation to the situation, and (2) *reconfiguring*, i.e. spatially reconfiguring objects in the environment. Both types of behaviour are considered proxemic transitions given that proxemics are enacted in an interplay between co-located people's bodies, physical artifacts and semifixed features that constitute the shared space. The purpose of the present work is to understand opportunities in designing for the latter.

To clarify what we mean by *reconfiguring*, we are not only concerned with furniture's ability to make physical transformations. Aligned with the argument of Lindlbauer et al. [230] we explore the potential for shape-changing interfaces in taking advantage of the combination of physical and digital transformations. In particular demonstrate with

ProxemiSurface how the spatial dynamics of both digital content and physical shapes complement each other in providing a flexible space for collaboration and interaction proxemics. The concept of proxemic transitions is unfolded in this paper by bringing attention to three aspects of people's transitions. Proxemic transitions remains as the top level theoretical perspective that contributes to the understanding of how adaptations and reconfigurations can be used as a design resource for shape-changing furniture.

12.4 Research Approach

The work presented here follows a Research-through-Design (RtD) approach [135, 216, 373]. Empirical studies of informal meetings in an open office environment have alternated with the design of ProxemiSurface in a mutually informing process of knowledge production. This approach is in line with recommendation from Oulasvirta and Hornbæk [278] to put more effort into integrative concepts, which link empirical and constructive solutions. In this work, proxemic transitions address this concern. The nature of typical informal meetings and design qualities of shape-changing furniture have been tied together in the concept of *proxemic transitions* – a theoretical concept which has formed the nucleus of research interest [278]. Design activities have enriched and deepened the concept in what Krogh et al. terms an accumulative fashion [216]. This approach allows for freedom of exploration while insisting on process transparency, and it acknowledges the complexity of designing shape-changing furniture for a real-world context.

Studies of Informal Meetings in an Open Office

In order to understand further the nature of proxemic transitions, we selected a context where we expected a high prevalence of transitions in how people move in and out of each others' proxemic zones [162]. As a result we studied informal meetings in open office of a local software and web development company. This place was selected since it has over the past years worked carefully to set up their open office environment in project-structured zones to support tightly coupled collaboration between software developers. Two of the authors spent a total of 20 hours (during two visits with 26 days in between) in the workplace. The focus was to understand the dynamics and transition in their collaborative work. We conducted observations of detailed transitions between individual work, informal coordination and smaller episodes of collaboration. Given the perspective of proxemics, we took detailed notes on how their spatial practices around collaboration formed in the context of the physical environment. Inspired by the methodology and spatial notation technique of snapshots [46], we captured spatial behavior (see figures 12.6 and 12.7). The field notes were supplemented with photos and video when possible. In addition, we conducted four contextual interviews. The collected material was compared and synthesised by the two researchers into typical scenarios and important qualitative examples were analysed in terms of their interaction proxemics and the proxemic transitions that people made.

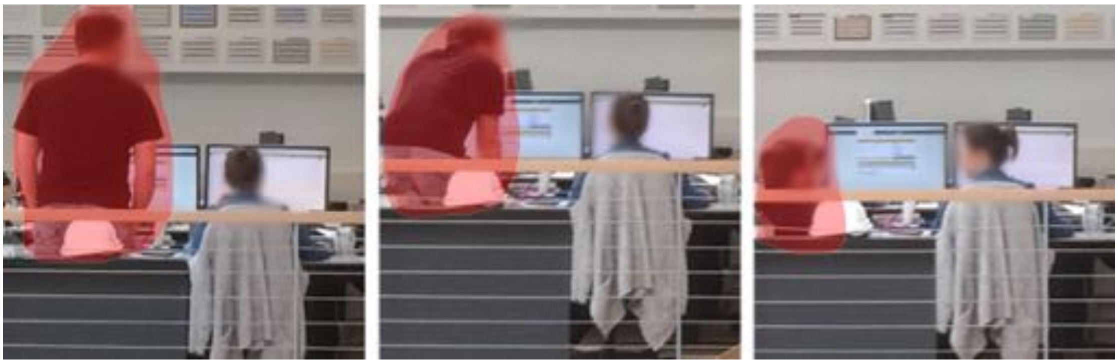

Figure 12.2: A proxemic transition into a longer-than-anticipated meeting with a colleague. The man to the left adapts his body posture to the environment and the duration of the meeting when he gradually moves from standing (left), to leaning (centre), and finally into squatting (right).

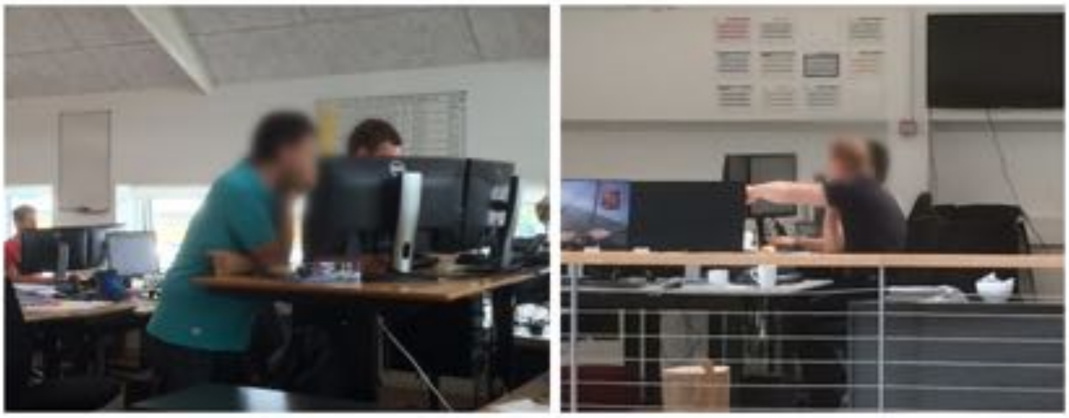

Figure 12.3: Two variants of sustained informal meetings. A pair both standing (left) and a pair both sitting (right).

12.5 Motivation for Shape-changing Furniture

The lessons from the studies of collaboration in open offices gave context to our initial design explorations. They further provided empirical motivation for the potential of shape-changing furniture. Even though coworkers each have their personal desk spaces, *informal meetings* play an important role in their everyday work practice. People continually transition between individual, pair and group work from minute to minute and sometimes even second to second. In particular, we observed how co-workers frequently move between personal workstations (with stationary computers equipped with large screens) to colleague's desktops making verbal exchanges of small bits of information or discussing something making reference through pointing to colleague's display. There was a high frequency of one-to-one interactions as a form of coordination work reemphasizing the importance of local mobility for collaboration [232]. Local mobility was well supported by the physical open office space, arranged with so-called office islands of four personal workstations arranged in a grid (see figures 12.6 and 12.7) and with a multitude of office chairs available including orange "guest" chairs. While coworkers very frequently transition between personal work and informal meetings at various durations, we found their mobility to be in sharp contrast to the inflexibility of stationary computers.

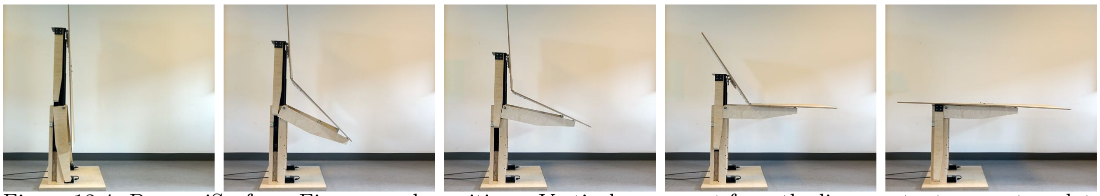

Figure 12.4: ProxemiSurface: Five example positions. Vertical movement from the linear actuators are translated into a pivoting movement that lifts the plywood arms and lifts the hinged table surfaces.

The insights from the workplace study fed into the prototyping sessions with ProxemiSurface in the form of typical scenarios. Analysis of interaction proxemics and F-formations provided ideas for supporting people's spatial behaviour in collaborations. Initially, we conducted bodystorming sessions with a first iteration of two individual tables having a surface capable of rotating vertically. This allowed us to experiment with various physical spatial configurations and projected digital contents while still learning about the physical constraints of a furniture-scale shape-changing artifact that would not reveal from an abstract sketch. The explorations involved manipulating with *orientation* of displayed content over time and with the physical orientation of the surface. The prototype setup enabled rapid prototyping of physical and digital transformations/animations to compare their respective qualities in terms of proxemic transitions.

As a result of our second visit to study informal meetings, we learned more about the challenges of the existing context in supporting proxemic transitions, which could be better supported by shape-changing furniture. Identifying typical scenarios it became clear that there were clear patterns in the duration of meetings, and that the duration was rarely planned in advance. For sustained meetings people would seek to continuously adapt and reconfigure to support the activity under the constraints of the current conditions, e.g. often passers by would lean over the table resting on their arms or squatting to make the digital contents equally accessible for the two people (see figure 12.2). Currently, the individual workplaces made it challenging for more than two people at a time to see the details of digital contents on the screen (see figure 12.3). In addition, mouse and keyboard always only allowed one person at a time to control the digital contents.

We built a refined prototype – *ProxemiSurface* – enabling smooth physical and digital transformation that allowed for exploring and enacting conceptual scenarios addressing the challenges outlined above. This includes addressing

1. different timings of informal meetings

2. gradual reconfiguring of a dynamic furniture in response to prolonged sessions

3. gradual reconfiguring of a dynamic furniture in response to shifting number of participants and activities

Together these findings motivate our design explorations of three design aspects of proxemic transitions as well as the design of ProxemiSurface.

12.6 Prototype: ProxemiSurface

ProxemiSurface is a shape-changing desk augmented with display surfaces using spatial augmented reality. The design is inspired by the notion of interaction proxemics [255, 272] in how it provides a flexibility for people to organize around shared display content in a physically dynamic way. The tables transform between vertical and horizontal configurations, ranging from being in a fully horizontal "table" configuration to a fully vertical "wall" configuration. During the transformation between the two endpoints, the prototype can take a hybrid "table + wall" configuration similar to BendDesk [354] and Curve [362]. Changing between these configurations changes the proxemics in regards to how a group of people can organize around furniture for pointing (deixis), controlling and perceiving the displayed content. The prototype has served as a token for envisioning and experimenting with shape change in informal meetings. In this paper, ProxemiSurface contributes as an instantiation of the theoretical perspective of proxemic transitions as an approach to designing shape-changing furniture for informal meetings.

The table consists of two parts held together by hinges. The table surfaces are fixed on top of two Linak^{TM} linear actuators positioned side by side . When the actuators are in the maximum position, the table surfaces literally hang in a vertical configuration. As the actuators move downwards, the construction translates the vertical movement by the actuators into a pivoting motion that slowly moves two plywood arms from a vertical to a horizontal position, supporting the rising surface (see figure 12.4). The hybrid "table+wall" configuration is achieved by pausing the movement as the table is moving into a horizontal position. Here the lower table half rests on the support arms while the upper half rests on the top of the actuators in custom mounting brackets.

The virtual graphics are projected onto the shape-changing desk through spatial augmented reality using a single projector placed above the desk. In order to do dynamic projection mapping during shape changes, each table surface is tracked using OptiTrack[1]. Digital content is displayed through an application built with the Unity3D game engine[2]. This application receives real-time user inputs through OptiTrack to detect physical transformation of the furniture as well as collisions between users' hands and the furniture surfaces for simulating touch events. Currently the physical shape of

[1] Optitrack motion capture system http://optitrack.com/. Accessed: September 2016

[2] Unity3d game engine https://unity3d.com/ Accessed: September 2016

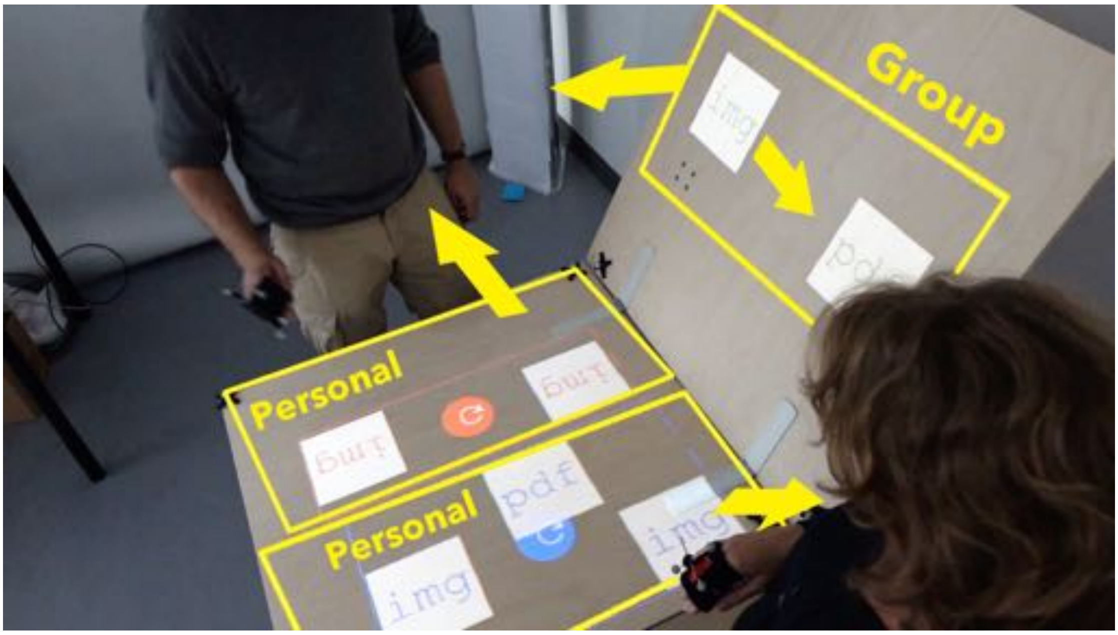

Figure 12.5: An overview of ProxemiSurface's user interface. Digital documents are organized within a territory marked with a dotted line in a personal color with a button in the middle of the territory for rotating its content.

the desk is controlled with a button press by a user. Since the focus of the paper is on explorations of the proxemic qualities of shape change, self actuation is not part of the scenarios with ProxemiSurface. However, future iterations could provide an API for controlling the desk such that the balance between user control and self actuation could be explored in detail, as proposed in [293].

Implementing a Spatially Dynamic User Interface

Surface textures in Unity3D display a web view that points to the URL of a web application, enabling the user interface to be implemented with web technologies (JavaScript, HTML5, and CSS3). The user interface consists of *territories*, which are content areas with a color associated with a user (see figure 12.5 for overview). Each territory contains a *rotation button* (for rotating its contents) and a collection of *documents*, e.g. PDFs or images, that can be flexibly reorganized and moved around. Territories can overlap, enabling documents from different users to be spatially distributed across the entire surface area of the physical prototype. The web application utilizes the web infrastructure of *Webstrates* [202]. This enables a simple way of connecting across devices, such that mobile devices can easily interact with the content on the surfaces of the shape-changing desk by communicating through a server. A mobile interface can be used to control the visibility of the content presented on ProxemiSurface, such that a view of a user's personal content can be quickly toggled on/off.

12.7 Design Aspects of Proxemic Transitions

Our iterative Research-through-Design process – involving design explorations with ProxemiSurface based on empirical examples of informal meetings – enabled us to unfold and articulate the design space for proxemic transitions. Our work elicited three design aspects of proxemic transitions:

1. **Transition speed:** The duration of a particular informal meeting has implications for the kinds of transitions people will make. Quick exchanges require support for high-speed transitions that involve a low transactional cost [255], whereas sustained informal meetings would benefit from more ready-at-hand tools for reconfiguring physical space.

2. **Stepwise reconfiguration:** Informal meetings are spontaneous and not planned out in advance, implying that participants *adapt to* or *reconfigure* the spaces they engage with in a gradual and stepwise manner as they move in and out of group and personal work. This can be designed for in shape-changing furniture by carefully designing the trajectory of its transformations with possible ergonomic steps between its endpoints.

3. **Situational flexibility:** Informal meetings need flexibility for participants to change the spatial circumstances for controlling and pointing at content as well as dynamically organizing in suitable F-formations around shared content. This is important, because it is not necessarily known beforehand whether the nature of the activity will shift, by e.g. the meeting going from containing two to five people within few minutes. Thus, it is important to consider dynamic furniture's abilities to accommodate a variety of activities and group sizes.

The following sections synthesize our understanding of the design aspects of proxemic transitions as it has developed. For each design aspect of proxemic transitions we account for how it manifested in the observations of the workplace study articulated in terms of snapshots [46], interaction proxemics [255, 272] and F-formations [196]. In addition, we demonstrate and reflect on a corresponding scenario with *ProxemiSurface* on how shape-changing furniture could support this aspect of proxemic transitions.

12.8 Transition Speed

The observational study indicated that the nature of informal meetings could often be distinguished by their *duration*, i.e., for how long the knowledge sharing and collaboration usually lasted before the participants moved on to other activities. Table 12.1 provides an overview of what we found to be typical informal meeting situations. As stated in the table, observed situations could roughly be divided into *quick exchanges*, *ephemeral meetings*, and *sustained meetings*.

Quick Exchanges

The examples indicate how the open space allows for quick exchanges in the office islands. The work stations right next to each other enabled quick transitions between personal and group work (see figure 12.7) in an ad-hoc manner. Figure 12.6 is one example of behaviour that can be characterized as a quick exchange, where two people sitting next to each other can make quick and frequent transitions between personal work and a short exchange. Other examples include talking to a colleague sitting across from you behind your displays or quickly walk over to leave a verbal message. Analysing the situation of figure 12.6, the proxemic transition is a very quick and temporary exchange, usually indicated in A's body language. In such situations, participants are reluctant to make more dramatic physical transitions like rearranging the space, as that type of behavior would signify a different kind of transition than what was intended by A.

Type of situation	**Duration**	**Examples of behaviour**
Quick exchange	Less than a minute	Talk across space,roll over.
Ephemeral meeting	Less then 5 mins	Roll over, walk over.
Sustained meeting	5 mins or more	Squatting, lifting table, or grabbing guest chair.

Table 12.1: Durations of typical informal meeting situations from observational study.

Ephemeral and Sustained Meetings

Ephemeral and sustained meetings often involved adaptation and reconfiguration in a number of ways. As illustrated in figure 12.7, where one person had tightly coupled collaborations with the colleague across. The perceptual proxemics of this situation imply that one would have to walk around in order to have shared visual access. In a "standing and sitting" formation as in figure 12.7(right), one is standing implying a more ephemeral exchange. The sustained informal meetings usually involved using the established physical configurations with either two seated next to each other or standing next to each other confronting a screen (see figure 12.3). We also observed examples of sustained meetings where colleagues would either adapt their postures around screens or would come to a point where they temporarily reconfigured the ergonomics of the environment by pulling over guest chairs or lifting the tables mechanically for a stand-up meeting. The proxemic transition in figure 12.2 shows a sustained meeting from the study. It exemplifies how coworkers adapt their posture to the environment and change the proxemic relation to a colleague. A man is standing next to a colleague's workstation initiating a discussion on a topic involving contents on the colleague's screen, then starting to lean on the table, and eventually squatting in front of the table to be at eye level with the screen and the colleague. This L-shaped F-formation is typical for a discussion involving displays. Prolonged discussions might cause physical strain on the standing colleague due to the configuration of the desk, display and printed documents –

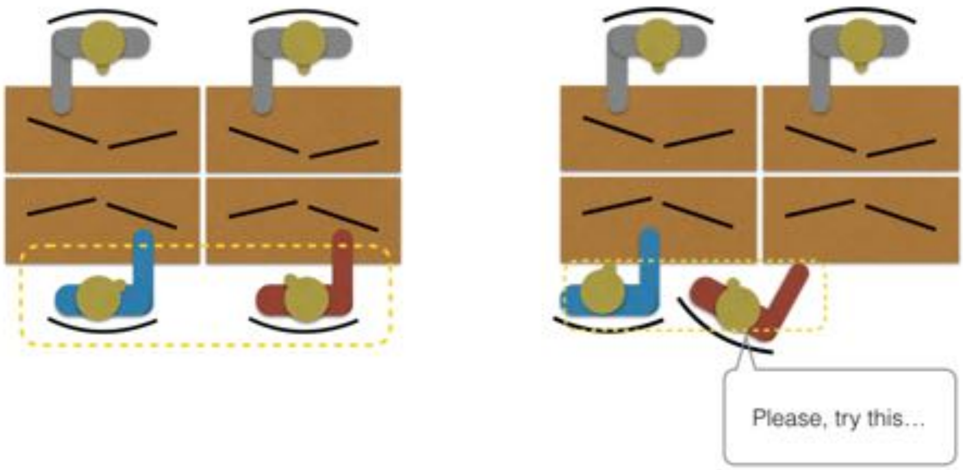

Figure 12.6: A quick transition scenario where person A (red) physically moves between her own (left) and B's (blue) personal work space to form a "2 sitting" configuration (right).

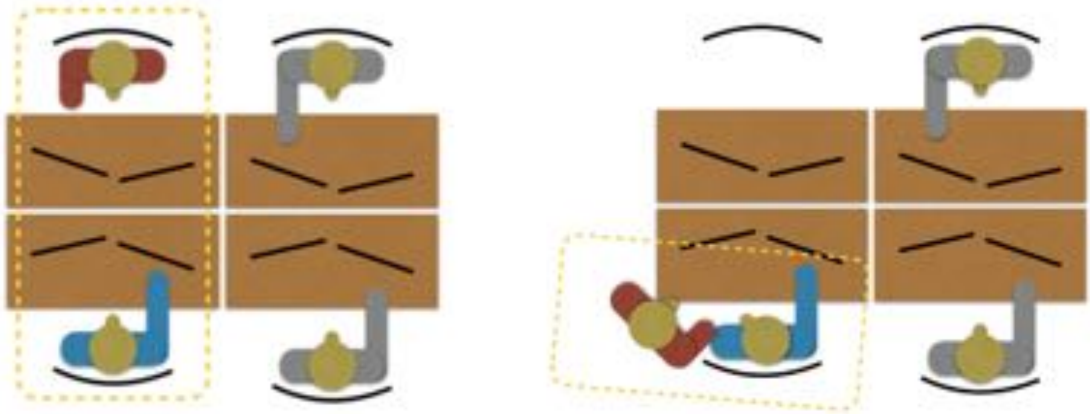

Figure 12.7: A transition scenario where A (red) physically moves between her own (left) and B's (blue) personal work space to form a "standing and sitting" configuration (right). This usually would manifest as an ephemeral meeting.

circumstances that make the colleague on the left change posture. As the above examples indicate, the temporal nature of a particular informal meeting has implications for which proxemic transitions might occur. In the following we consider how this can be supported by shape-changing furniture.

ProxemiSurface: Transition Speed

The design space of shape-changing furniture enables us to rethink the way people can get into place for collaborations by providing new mechanisms of organizing space. The three types of informal meetings relating to the duration of meetings and speeds of transitioning can help us design for this aspect of proxemic transitions. In ProxemiSurface, *speed* is considered carefully in its ability to support both quick transitions through digital spatial transformations and more radical transitions through physical transformations. Inspired by the large diversity in types of informal meetings and research on speed in shape-changing interfaces with projection mapping [230, 308], the following scenario with ProxemiSurface seeks to illustrate how we can design for different transition speeds. To illustrate how digital and physical transformations complement each other in supporting various transition speeds, the following scenario contains a quick informal exchange (as illustrated in figure 12.8) and a prolonged exchange (as illustrated in figure 12.10):

> ***Quick exchange:*** *Alice and Bob are doing individual work on a shared project at their personal workstations. They are both evaluating notes and pictures from a large field study. Alice has some questions to the study, and she walks over to Bob to ask for his opinion. Bob opens up a digital space on the display, and using her mobile device Alice quickly brings up a photo in the periphery of Bob's vertical display surface (see figure 12.8(A-B)). After Bob has expressed his opinion, Alice turns back to her seat leaving the photos for Bob to consider in his evaluation.*
>
> ***Sustained meeting:*** *Tom arrives at Bob's desk because he has finished a draft of his collection of tagged photos (see figure 12.10(A)). Bob is nearly ready too, and they decide that they want a bit more space, such that they can have their personal stuff at the desk, while sharing a larger display area for collaborating (see figure 12.10(B)). Tom and Bob can now organize their photos and sketches together in a larger space, while being able to maintain each their personal space.*

In the above scenario, the situation in figure 12.8(A-C) requires Alice to walk up next to Bob in order to create a formation with perceptual and deixis proxemics [255] where they can easily face each other while accessing a shared display. However, the significant quality of the first interaction is how it involves a certain type of *loosely coupled* collaboration with a quick exchange. In these types of quick exchanges, shape change could be distracting and inappropriate. Alice's intention is not to reshape the environment for a discussion, but rather getting a response in order to continue her work. However, in such situations people still need a flexibility for being able to maintain their personal space while shortly sharing a space for collaboration and discussion. In the interface design, we considered proxemic zones, i.e. territories, in how digital content can be distributed spatially. Being able to move digital documents and territories like physical documents provides a dynamic space that is flexible in how it enables people to keep their personal space, while simultaneously being able to have a shared space for pointing to and referencing during a discussion. Notice how speeds of transitions are annotated in figures 12.6 and 12.7, respectively. This shows how ProxemiSurface provides a low transactional cost [255] in digital transformations that only require a

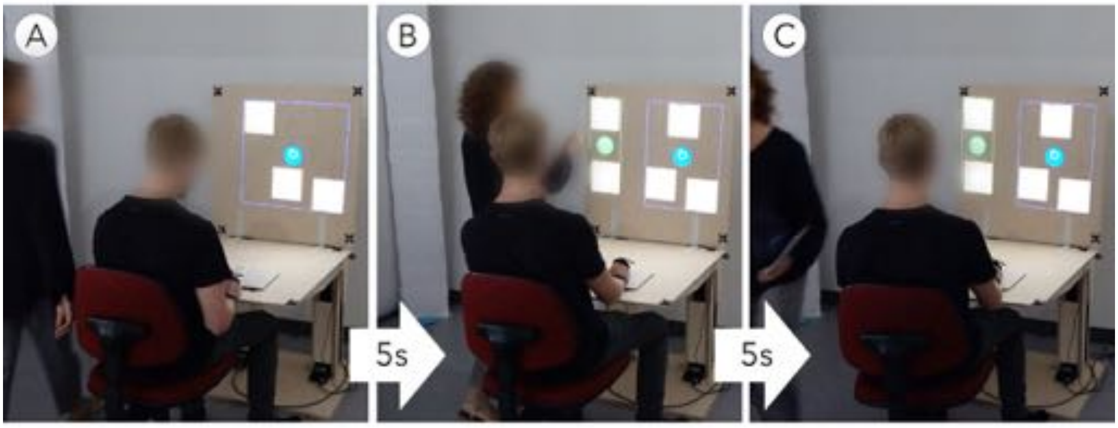

Figure 12.8: *ProxemiSurface* supporting quick exchange: The digital space is adapted to accommodate two users. (A) Bob works at his personal desk as Alice approaches. (B) Bob invites Alice by bringing his content to the side, and Alice brings in her content to quickly convey an idea to Bob. (C) Alice leaves and Bob can go back to personal work (now with a digital copy of Alice's idea).

few seconds, while the physical transformations involving shape change occur at a lower speed and have a higher effort cost – only valuable to some types of informal meetings. We refer to the video of ProxemiSurface[3] for getting a clearer sense of how speeds of physical vs. digital transformations are experienced.

12.9 Stepwise Reconfiguration

The second design aspect of proxemic transitions is *stepwise reconfiguration*, i.e. how people gradually change their circumstances for collaborating during informal meetings. The nature of informal meetings is that they are unplanned, and they occur frequently and spontaneously. Physical transformations, such as moving up and down the table, are limited to a certain speed and this has implications for how people might either adapt to or reconfigure their environment. The main point of the following examples is that involved participants make ad-hoc adaptations and reconfigurations to the situation while not being entirely clear in advance how the informal meetings will evolve.

A series of snapshots from a time period of only 5 minutes in figure 12.9 illustrate that along with the speed with which knowledge exchanges occur, people's gradual and stepwise adaptations and reconfigurations are an important aspect of the nature of proxemic transitions. People adapt their positions to better align with whom they are in conversation with, and this occurs in an ad-hoc and unplanned manner that involves multiple steps progressing towards a negotiated resting situation for their conversation. These spatial negotiations occur as a parallel activity while attention is on the conversation.

[3] See the video accompanying this submission.

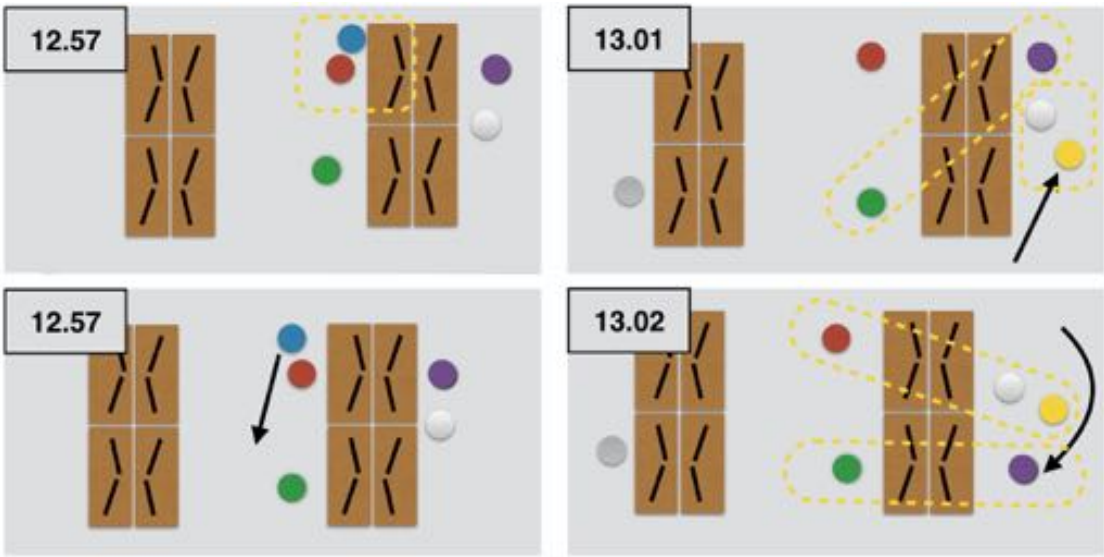

Figure 12.9: Stepwise adaptation. *12.57:* People doing individual work, while red and blue are in dialogue. *13.00:* As blue moves back, red puts on headphones to focus. *13.01:* Green and purple initiate a dialogue, while another starts between white and yellow. *13.02:* Purple leaves his desk to be able to talk to green without interfering with the others. Red could eavesdrop the conversation between white and yellow and joins.

Zooming in on the spatial negotiations that occur in situations involving multiple parallel informal meetings, a particularly interesting snapshot from the field notes goes as follows:

> *As coworker A was away from his workstation, coworker C came by to talk to coworker B while A was away. He borrowed the free chair, and once A came back again, A and C had a quick exchange, and A just lifted his table, so B and C could continue their sustained informal meeting.*

This illustrates very well a characteristic of the ad-hoc behaviour revolved around informal meetings, namely how people use certain mechanisms in semifixed-feature space, e.g. borrowing a chair for quick transitions, whereas the more radical, such as e.g. lifting a table, is used as a workaround when it is necessary to stand because one's chair is being borrowed. This example contrasts the example of a colleague squatting for a one-to-one prolonged discussion in figure 12.2 in that one is about adapting one's posture and the other is about reconfiguring the environment. However, both involve transitions that aim at changing the physical circumstances for collaboration, i.e. organizing for certain interaction proxemics. Together these examples pose a challenge for how designers can support proxemic transitions, in that a) due to the ad-hoc nature of informal meetings the progression cannot be predetermined, and b) the spatial reconfigurations are complex and socially situated, implying that – rather than alone designing radical end-to-end transformations – stepwise reconfigurations must be enabled in shape-changing furniture.

ProxemiSurface: Stepwise Reconfiguration

The following is motivated by proxemic transitions ending with one in a squatting position (figure 12.2) or a gradual rearrangement of furniture (figure 12.3) as described in the above empirical examples. We explore how opportunities for new proxemic transitions might be enabled by shape-changing furniture, providing the possibility to choose different spatial ways of progressing and sustaining informal meetings. Supporting proxemic transitions involves attention to coworkers' unplanned progression. Thus, ProxemiSurface is designed to enable users to *gradually* reconfigure the environment. Not knowing in advance how long an informal meeting takes might prevent one from radically reconfiguring the environment. Being able to decide on stepwise smaller improvements rather than making drastic changes to the physical environment would provide more flexible choice and could potentially have an impact on the proxemic transitions in situations such as figure 12.2. Design of the transformations in shape-changing interfaces is often merely describing the start and end states of a shape change, but considering the entire trajectory might be crucial to its usefulness for supporting proxemic transitions.

Stepwise reconfiguration is designed for in how ProxemiSurface can transform in a trajectory between wall and table display, while also providing opportunities for being a hybrid with a mix of vertical, horizontal or even 45-degree angles. We found during body storming with the first prototype iteration with two separate rotating tables that the hybrid configuration of figure 12.10(B) provided a unique situation for collaboration. Prior work on comparing horizontal and vertical surfaces in relation to collaboration [261, 304] point toward different properties in how they support different activities. The below scenario illustrates how mixing vertical and horizontal surfaces might provide additional flexibility. ProxemiSurface allows for physical transformations with multiple configurations along the trajectory between two end points, and the value of this is demonstrated through a scenario of stepwise reconfiguration (illustrated in figure 12.10).

> *Tom wants to share an idea with Bob. He comes over to Bob's desk to quickly make sure that they align on the idea.*
>
> *Bob responds and Tom is about to return, but realizes he wants to show something else. The current physical configuration allows for Bob to walk around on the side and bring his digital territory with him, allowing Tom's personal display area to expand (see figure 12.10(B)). This transition turns the display space into a shared space accommodating both group and personal display territories.*
>
> *Tom and Bob discuss and compare ideas at Bob's workspace for five minutes. They have reconfigured themselves in a face-to-face formation [196] with the shared vertical surface on their side and two personal territories on the horizontal surface with each their display area orienting towards themselves.*
>
> *As they reach common ground, Bob suggests that they spend a bit of time combining their work. At this point, they realize that they need a slightly*

Figure 12.10: *ProxemiSurface* supporting ephemeral/sustained meeting: The transformation of ProxemiSurface interplays with Tom and Bob's stepwise transitions; (A) Tom and Bob reorganize for sharing the space around the desk. (B) They adjust the furniture for better viewing angles. (C) They reorganize to be able to collaborate closely and compare documents.

> *different setup for more easily co-creating documents. Thus, they bring down the table to sit in a side-by-side arrangement [196] with a larger space for collaboration (see figure 12.10(C)).*

What is to be noticed from the above scenario is how Tom and Bob initiate an informal meeting with a quick exchange, however, as it is sustained they gradually move toward a more tightly coupled collaboration by continually and gradually making proxemic transitions, i.e. either adapting their F-formations to the interface or reconfiguring it to change the deixis and perceptual proxemics. It further illustrates the continuous negotiation of space between participants that was described in the empirical findings. By supporting a range of opportunities for manipulating the shared artifact, manipulating digital content, reconfiguring the physical surface or both, ProxemiSurface provides an example of how to design for the ad-hoc nature of informal meetings through the design aspect of stepwise reconfiguration.

12.10 Situational Flexibility

The final aspect of proxemic transitions that this paper brings forward is *situational flexibility.* An important aspect of people's local mobility was their movements between different spaces to organize in an environment with the suitable F-formations and interaction proxemics to serve their particular purpose of collaboration and group size. A snapshot from the field notes illustrates how certain properties of a space cater to certain group sizes.

> *Three coworkers A, B, and C are organizing around a whiteboard. The whiteboard - because of its size and orientation on a wall - supports F-formations involving more than just two, where all can easily see the content, point to*

it, and switch between who has the pen to produce the content. Also people can easily switch between orienting towards the content and each other. At one point they have to discuss something that involves the digital content on A's machine. A and B move over to A's computer display to continue the discussion afterwards, while leaving C at his desk close to the whiteboard. A controls his computer, and B has visual access, but is only able to interact with the content through A, unless B takes over A's seat.

As noted in this description, the whiteboard enables flexibility by its easy access and openness towards multiple people. As touched upon by Rogers et al. [304], wall displays were superior for changing group sizes and presenting material, whereas tabletops supported close collaboration at limited group sizes better. An advantage of vertical surfaces is that people can organize in a semi-circular F-formation [196] around them with equal visual access and deixis abilities in relation to the content. In contrast to their personal workstations, it provides a flexibility regarding who has the control of producing content (i.e., who has the pen), thus providing different control proxemics more suitable for collaborations and discussions at larger group sizes.

When A and B leave C to look at A's computer, the current collaborative situation transitions into a new situation where A and B work closer together and C is left for personal work. If the meeting with C was intentionally concluded, everything is fine. However, the spatial circumstances are inflexible for sustaining the informal meeting in a group of three with access to a shareable large surface and personal content from their workstations. It was very rare that three people would organize around a display at a personal workstation due to the limited amount of space. Thus, the physical circumstances constrain the space of possible proxemic transitions for sustained informal meetings involving display content.

ProxemiSurface: Situational Flexibility

In line with Heath & Luff's characterizations of ecological flexibility [232], we demonstrate how spatial adaptation is enabled by ProxemiSurface to allow for adapting to a variety of situations and interaction proxemics. Careful attention is given towards the dynamics of *orientation*. In related furniture-scale shape-changing interfaces there is usually either a focus on vertical dynamics as in the Shape-Shifting Wall Display [147] or horizontal dynamics as in TransformTable [335] or inForm [226]. What we found to be a significant aspect of knowledge sharing using displays is flexibility to reorganize for changing the interaction proxemics involving a mixture of horizontal and vertical surfaces. The design of ProxemiSurface builds on the findings in Rogers et al.'s comparison of vertical and horizontal displays [304]. Our findings indicated quick transitions between informal meetings that involved both cohesive collaboration and a variety of group sizes. ProxemiSurface is thus an experiment on orientation of digital content space using vertical and horizontal surfaces. The following scenario (illustrated in figure 12.11) demonstrates how a group might use such a flexibility to rather reconfigure space of the current location for interaction proxemics that allow for a larger group.

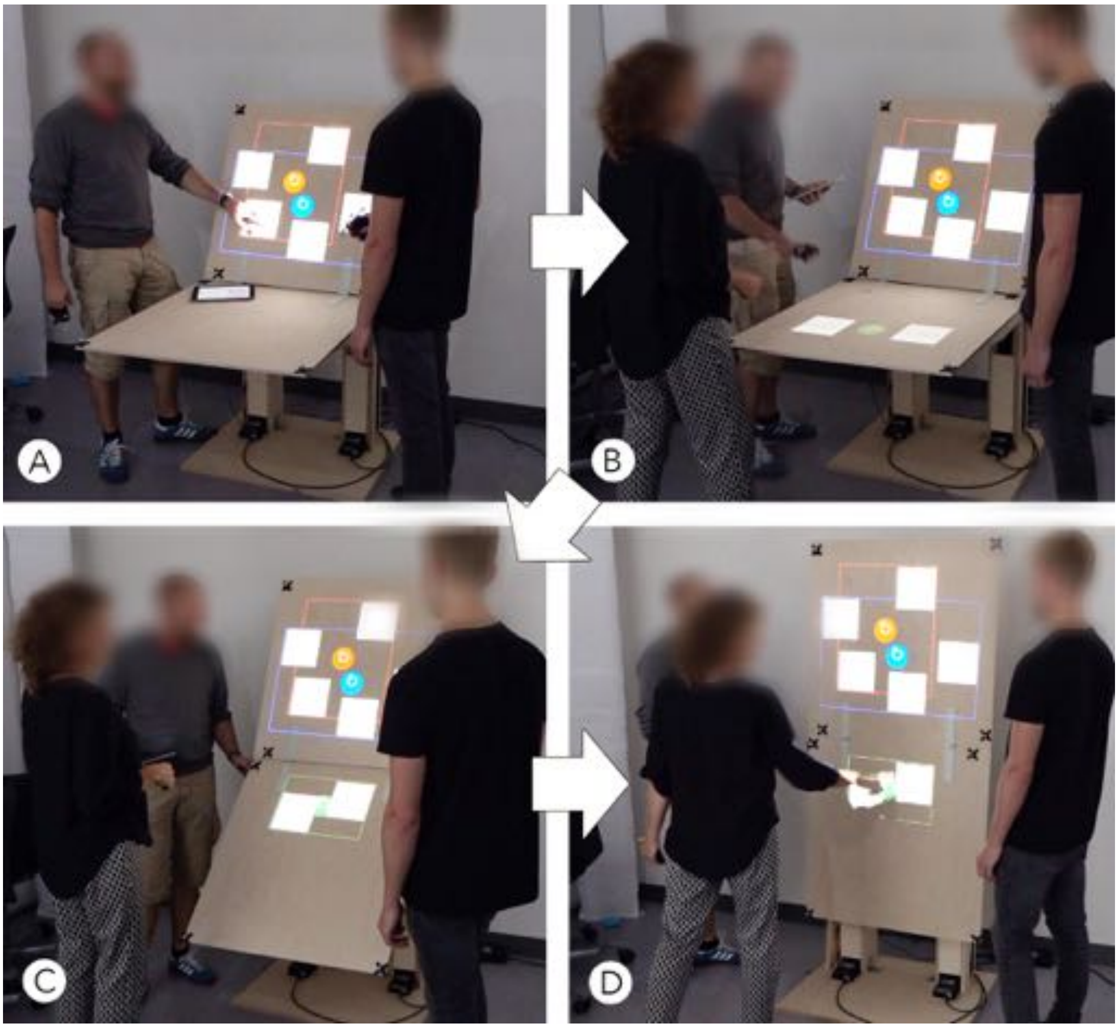

Figure 12.11: The workplace is spatially flexible and enables reconfigurations to accommodate various group sizes.

Tom and Bob are comparing diagrams (see figure 12.11(left)). Alice spontaneously joins the activity. She stands at the end of the table forming a semi-circular arrangement of people around the furniture. Tom and Bob move up one end of the desk to have a vertical surface that they can all see fairly well. Alice can easily bring up her personal items on the table using her mobile device.

In this configuration, however, Tom and Bob have privileged access for controlling and pointing to most of the surface. It is hard for Alice to gesture and point properly on the details of the vertical display, so she asks whether they could transform the space into a fully vertical configuration. Tom transforms the surface into the "whiteboard" configuration (see figure 12.11(right)). This allows the group to still form a semi-circular arrangement, now all three *being at an arm's length from controlling and pointing towards the shared display.*

What is interesting about the above scenario is how shape change provides a new dynamic space for enacting territoriality and proxemic zones in collaborations. Scott et al.'s study three types of territories around tabletops; personal, storage, and group territories [315]. The above scenario illustrates how a shape-changing interface provides a new way of organizing territories on vertical and horizontal surfaces and how they can change the physical circumstances providing a different territoriality. Notice how Tom and Bob were able to conveniently share a storage space on the vertical surface because of its balanced orientation towards the two collaborators while having their respective personal zones. As Alice enters they change the configuration to enable Alice to become part of the group territory and give all equal access in terms of control, deixis and perception. This scenario is also supported by the comparative study of [304] investigating how vertical and horizontal surfaces support different types of activities.

Being able to relatively rapidly reconfigure the workspace between a table and a wall display provides a situational flexibility that enables the space to invite for various group sizes (in this case moving from two to three) and thus enable a variety of collaborative situations. The proxemic transition with shape-changing furniture might be as radical as moving to another work area with a whiteboard, but in case the session would benefit from maintaining the same digital environment, this would provide a new way of conducting the collaboration. It is worth noting again that there is a transactional cost [255] associated with any person manipulating the physical configuration, assuming that this is one colleague's personal desk. However, the point of this scenario is rather to illustrate how proxemic transitions with ProxemiSurface enables new flexible ways of organizing around displays. How this type of flexible artifact might find its place in an actual work environment – whether it being a personal desk or a dedicated desk for informal meetings – is a question for future work.

12.11 Discussion and Conclusion

Learning from theories of proxemics, conducting empirical studies and iterative design work, we have illustrated how shape-changing furniture can be meaningfully designed to support proxemic transitions, and we have highlighted three aspects to consider in the design of such furniture. ProxemiSurface breaks new ground in the area of shape-changing surfaces with its dynamic horizontal and vertical surfaces in the same form factor. In addition, it serves to articulate the conceptual contribution of proxemic transitions as a characteristic of collaboration and as a design quality. The specific interaction design of ProxemiSurface has not been explored yet, and it will include elements of both implicit and explicit interaction [147] and different levels of control and initiative between the user and ProxemiSurface [293]. Interface evaluation at this stage is therefore premature, since beyond this perspective lies a design space awaiting much further detailling and exploration. Finally, it is important to recognize that, how shape-changing furniture will be adopted in a specific context will always be a complex interplay between politics, power, culture, habits, and interaction design. Thus this paper represents only an initial investigation into this exciting area by contributing with the perspective of proxemic transitions and the design of ProxemiSurface.

Chapter 13

Publication VI: local.here: Ubiquitous Computing from a Place-centric Perspective

`local.here`: Ubiquitous Computing from a Place-centric Perspective*

Henrik Korsgaard and Clemens Nylandsted Klokmose

Abstract

This paper revisits and interprets Weiser's vision of ubiquitous computing as a place-centric vision. Weiser argued for *"the preservation of local substance and sense of place"* and *electronic places* as a way of balancing the placelessness of technology. We propose place-centric computing as a sub-genre of ubicomp that emphasises: 1) the particularity of places, 2) integration with existing infrastructure and systems, 3) understanding users as inhabitants, 4) local control and authorship, and 5) using the nesting and bounds of the real world as key principles. We present a simple software architecture for place-centric computing based on the concept of *information substrates* and a WLAN based approach to coupling information substrates to particular places. We present a proof-of-concept system *local.here*, two scenarios of use and their implementation, and evaluate *local.here* from a systems perspective. This approach potentially support inhabitants in developing local information spaces as part of their activities.

13.1 Introduction

In this paper we revisit and interpret Weiser's [350] vision of ubiquitous computing as a place-centric vision. Rather than supporting personal computing anytime, anywhere, Weiser described his goal as embedding hundreds of computers per room with the purpose of enhancing the physical world and supporting work environments as a *"pleasant and effective "place" to get things done"* [350, p.100]. In the 1991 paper, meeting rooms, offices, whiteboards etc. made up the dominant environment and the local area infrastructure tied together the stationary shared devices (board-sized displays, printers and file servers) with the mobile devices (tabs and pads). For Weiser, computing was not

*Draft in preparation for submission to the 2017 International Joint Conference on Pervasive and Ubiquitous Computing

a matter of connecting a personal device to an information resource from an arbitrary location, but instrumenting and connecting distinct and meaningful places (Sal's home, her office, offices of colleagues, the East Coast office etc). He argued for *"the preservation of local substance and sense of place"* and *electronic places* as a way balancing the placelessness of technology[1]: *"As network resources replace placeful resources, we will reach the point where we need more electronic places. This article tries to head off going too far with placelessness, to add constraints to Internet architecture today so it can be placeful tomorrow, and to temper naive enthusiasm for a completely placeless existence."* [295, p.36]. In other words, when the development of networked and personal computing follows the ideal of anywhere/anytime, there is a danger that we forget the role that particular places, which we inhabit and play in, have in shaping our lives and experiences. As a response, Weiser suggests developing networked technology that support and give precedence to local activities situated within familiar places, such as libraries and other community spaces. This is the foundation for our work.

Interpreting Weiser's work as place-centric is more than an academic exercise. Although today's hardware, software and infrastructure exhibit many of the traits of ubiquitous computing, the particularity of local configurations challenges getting into place and getting work done [74, 115, 150, 197]. Consider the steps involved in taking a photo of a whiteboard and then wanting to print it using the nearest printer. This small task quickly spans multiple devices, knowledge of and access to the resources on the local area network, a compatible devices and drivers. Imagine how the complexity changes if attempting to complete the task as a visitor, if in a semi-public place, or wanting to print on the nearest *available* printer. This example only illustrates a small part of the complexity involved in making full use of the multiple heterogeneous computational devices within our proximity. It conveniently abstracts away the particularity of local configurations, the fact that printers are most likely the simplest shared device on the network *and* the local meaning and spatial organisation of the particular place wherein the task is embedded. What if those using the particular place – let's say an office environment – wanted to extend the functionality of the printer to allow anyone sending a print job from a mobile device situated next to the printer to jump the print queue? Or wanted to configure the light panels in a meeting room to dim when something is running on the projector? Add computational behaviour to a common area in the office, or realise Weiser's short scenario: *"The telltale by the door that Sal programmed her first day on the job is blinking: fresh coffee."*? [350, p. 102]

According to Klokmose et al. [201] the fluent interplay between people and computers, as present in Weiser's vision, is today inhibited by how we build and think about software: Modern software is brittle and hard for users to change, and support for collaboration between people and distribution across heterogeneous devices are today

[1] See [110] and [355] for related analyses.

exceptions rather than norms. Although these shortcomings have resulted in various services offering synchronisation and sharing (e.g. Google Drive, Dropbox etc.), we see these as symptom treatment. As an alternative to the current application-centric software paradigm they introduce the concept of *information substrates* (substrates for short) that "... are software artifacts that embody content, computation and interaction, effectively blurring the distinction between documents and applications." With the web-based system *Webstrates* they demonstrate how this model is realisable and how it enables a number of uses that includes software malleability and personalization, collaboration through personalized interfaces, remote user interface extension at run-time, and orchestration of complex distributed and collaborative user interactions.

In this paper we address the need for approaches to ubiquitous computing environments that allow people proactively to take control over, appropriate and extend the capabilities of the places they inhabit. We propose a substrates-based approach to place-centric ubiquitous computing prototyped with *Webstrates.* This approach allows users to bound and define their local information spaces, nest substrates representing place, people and objects within the information space, extend the functionality of familiar devices, and augment places using familiar web development tools, ultimately supporting users in creating *electronic places.* The work addresses known challenges within ubiquitous computing, e.g. heterogeneity, discoverability, interoperability, and user interaction [2, 81, 197], a need for end-user control [302, 349] and programming frameworks [1, 81, 197], and theoretical and conceptual work on place and place-specific computing within HCI and interaction design [75, 93, 193, 253, 256].

In the following we present the idea of place-centric computing hand the implications this presents. Then we introduce *local.here*, a proof-of-concept system that combine existing network infrastructure, proximity sensing nodes [200], and substrate-based dynamic medium [201] to demonstrate the ideas and potential of a place-centric vision of ubiquitous computing. Briefly, the approach and implementation support a human-centric approach to developing local ubiquitous computing environments that emphasise the particularity of place and local control and development. We begin by presenting place-centric computing and outline the dynamic document-centric model, followed by an introduction to *local.here.* We juxtaposition our work with related work and demonstrate the potential in the approach through two scenarios. We evaluate and discuss potentials and limitations in the presented work.

13.2 Related work and current challenges

Its been 26 years since Weiser presented his vision, which has fuelled research in ubicomp and HCI since. Yet, we are still far from the kind of computing envisioned. Researchers seem to subscribe to two different positions, one emphasising smart environments and proactive systems catering to contemporary personal computing, and another study how ubiquitous computing unfolds in the present through proactive users (see discussion in

[36, 277, 302]). Regardless, there are still common and relevant challenges: Discovering what services, people, devices are around you and what possible synergies might arise from (ad hoc) interoperability [114, 197], adaptation, configuration and interoperability in a ever changing world [17, 81, 197], who should configure and maintain the ubiquitous computing environment [115, 239, 302], integration with the physical world [2, 197], and finally development of software for ubiquitous computing environments and tools for programming said environments [1, 17, 81, 197, 302]. We share the sentiment with [193, 302, 349] in the position that it is people who should be in control of, and take on an active role in, designing their local ubiquitous computing environment. This necessitates adequate tools for instrumenting environments and developing ubiquitous computing environments. This work is partly an attempt to answer Kindberg & Fox' question: *"What does it mean to write "Hello World" for a ubicomp environment?"*[197, p.73]. An answer is necessary if we want to pursue the ideals of proactive users maintaining local control and ownership proposed by Rogers [302].

Context aware-computing

Substantial work on context-aware computing have looked at software infrastructure that combine sensor and environmental data, user and system data, and location data in to a coherent location model (see [13, 170, 179] for extensive reviews). Dey et al. [103] describe places, people and things, and Chen et al. [90] develop ontologies describing places, agents and activities in the Context Broker Architecture. The most relevant is Hong & Landay's proposal of an infrastructure perspective to context-aware computing. Supporting context-aware features as part of infrastructure is advantageous because it is independent from hardware, operating systems and programming languages, and provide some scope for sharing of sensors, processing power, service and data [178]. In *local.here* we utilise common network infrastructure and create scope based on network presence and proximity. Dey et al. propose a Context Toolkit that provide a set of context abstractions to support the development of context-aware applications. Their concepts of *aggregators* and *discoverers* are somewhat similar to the role place and substrates play in *local.here*.

Recombinant computing

Recombinant computing [115–117] seek to address the fundamental challenge of creating ad hoc interoperability across heterogeneous devices. In recombinant computing (and the implementation Speakeasy) each device and service on the network is treated as a potential component and the system allow these to interoperate and be recombined in ad hoc scenarios. Each component implement a small interface allowing the component to discover other components, common protocols and information on user interface delivery. We share the basic ambition of supporting interoperability and combining capabilities of multiple services and devices, but approach it differently. In *local.here* each device is represented by an information substrate wherein the user defined the functionality of the device. Recombination then happens when two or more substrates are combined to create aggregated or extended functionality.

Roomware

Many systems have focused on developing roomware and setups targeted specific environments and activities. Common for the systems is that they mix physical components, shared screens, chairs, tables etc., with network and server infrastructure delivering content and functionality. iRoom [187], SMaRT [345], WeSpace [360] and InSpace [344] all represent systems and setups designed for meetings and meeting spaces. In iRoom, a room operating system combines displays and input devices. The researchers have slowly evolved the setup throughout the years, and included support for prototyping user interfaces [15]. I-land [327] and InSpace are both examples that use custom furniture to create the space and support collaborative meetings. The systems are designed for particular places with the purpose of instrumenting the meeting activities. The infrastructure and software components are tied to the particular setups, with little consideration for generalisation into general software infrastructure. Streitz et al. [325, 327] strongly emphasise coupling physical locations with virtual counterparts. This is achieved by using what they call Passengers, i.e. physical tokens that can be recognised by the other roomware components. InSpace achieve something similar by using RFID tag to identify clients, whereas WeSpace require a software client to be installed on personal computers for them to be usable in the system.

Coupling the physical and digital

Much work has examined how to couple physical objects with digital entities. Fitzmaurice [125] work on situated information spaces share a lot of similarities with our work. He advocated using spatially aware mobile devices to visualise and filter information, by interacting with information hotspots and mediator objects in the environment. These mediators can reach and interface between the physical and computational environment. The core tenet in this work is to use the *"user's persistent mental model of the office environment and provides a constant analogy to the physical interface for accessing or viewing objects."*[125, p.47]. *local.here* share the emphasis on anchoring information in relation to real objects and creating situated information spaces. In our system, we use proximity sensing to establish mediating objects and network infrastructure to make the coupling. There exist a few systems that have sought to combine location-based technologies with web and hyper-media systems included [156, 157, 198]. For instance, the CoolTown system [198] provide infrastructure for things, people and places. Many of the core functionalities in CoolTown are similar to that of *local.here*. Physical objects are instrumented and discovery happens via network broadcasting to a PlaceManager. Association then happens through a resolver service and further communication via HTTP. The core idea that web-present places contains web-present representations of the people, places and things within. This is similar, yet different to *local.here*. Whereas

CoolTown rely on hyperlinks alone and conceptualise places as hyperlinked collections, *local.here* use both hyperlinks and transclusion to support nestedness and containment.

Proxemics

Recent research in ubiquitous computing has started examining how proxemic relations between people, digital devices, and non-digital objects might be useful from an systems perspective. Based on Hall's [162, 163] concept of *proxemics*, Ballendat et al. [16, 149] have developed five dimensions of position, proxemic relations orientation, movement, and identity. Through a series of small examples, they show how these parameters can be useful for handling different level of awareness and offer proximity dependent interaction possibilities. Sørensen et al. [319] show how proxemic interaction can be useful in scenario where a system spans multiple rooms. Proximity is an important aspect of place-centric computing and in *local.here*. The system support sensing proximity to a particular location and differentiating between multiple positions. What exactly happens when users move into or change proximity is a matter of local configuration.

Place and space

Finally, our work take inspiration from and build upon the large body of work on place (and space) within HCI. Interest in place in HCI has drawn substantial theoretical influences from human geography (e.g. [74, 93, 94]), semantics (e.g. [169]) and related traditions. Place was initially introduced as a theoretical lens and/or metaphor [122, 148, 168], and with the advent of mobile computing and more interactive interactive environments, as a (phenomenological) perspective on how places shape human experiences and the role that this might play in design [94, 109, 193]. Brown & Perry [74] make an interesting distinction between technology as either more spatial or placial. In their analysis, space refers to the abstract process that organise our understanding of the material world, whereas place refer to the messy reality of the real world and that technology is used in particular places. Ciolfi & Bannon [94] and Kaptelinin & Bannon [193] propose focusing on technology enhanced activity spaces. Kaptelinin & Bannon emphasise development from within, as intrinsic practice transformation. McCullough argues for place-centered interaction design that emphasise the human need for getting into place [253]. One important challenge is to balance uniformity (which he equates with contemporary technology, see also [74, 331]) with the character of specific places and human habitats. Messenter [256] follow this trajectory and argue for place-specific computing as an genre of interaction design.

Positioning our contribution

The present work contributes to the body of work outline above. Although we share high level architectural components and considerations with context-aware computing, our perspective differs fundamentally on a) who should create and manage the context, b) and the interest in modelling the context (see [108]. With our emphasis on particularity (which is hard to model) and local control, we pursuit a less centralised and systems-oriented approach to context-awareness. In our system it is the inhabitants that should be in control, establish and define their local environment, as more than context to individual use and personal computing.

We share aim and outlook with work on room ware and recombinant computing. The idea that either the physical environment or the network encapsulate what is within and offer means of integrating and utilising interoperability to foster local configuration is pivotal in our work. Our contribution is a general approach to 'room' discovery and integration, and a software environment that allow inhabitants to configure and program the environment. We do not contribute by theorising and adding to the theoretical work on place within HCI. Rather, we attempt to build on that work, operationalise core concepts and explore computational alternatives [208] for place-centric computing.

13.3 Place-centric computing

Place-centric computing is an approach to computing that makes *place* the primary entity in the development of ubiquitous computing environments. Place-centric computing acknowledges that places are unique and particular. A place is somewhere, it is a unique geographical location (but not just a set of coordinates), it has material form, physical appearance, and local cultural-historical meaning[2]. We cannot escape the everyday physical world we live in [75]. From a computing perspective, we are always confronted with the messy nature of real world computing, layers of complex infrastructure, constellations of heterogeneous technologies and local practices [36]. This necessitates grounding system designs in the social and cultural practices, the built environment and existing organisation of artifacts and interiors of a particular place [253, 256]. The work here is an attempt to operationalise what *grounding* implies from a software perspective, so in the following we we summarise three premises of for place-centric computing and their principal implications.

Premise 1: Reality as foundation

Place-centric computing is bound to the physical world. We live in a meaningful environment, a stable world of surfaces that afford and structure activities. Terrain, pathways and walls partition the world and affect how people move within, interact with, socialise and experience, their environment [138, 163]. The built environment today is designed to support specific activities, from the basic features of a home to highly specialised functional spaces, such as a lecturing hall or a hospital. Given the particularity of places and its physical environment, place-centric computing should follow the organising principles of the real world. First, places are distinct and *nested*. Rooms are in buildings,

[2] This definition of place is developed from two recent theoretical reviews by Gieryn [140] and Ciolfi [93]

buildings are in neighbourhoods, neighbourhoods are in cities and so forth. Second, places are stable containers that enclose and *persist* whatever is inside. Stuff can only be in one place at a time and whatever is in a given place often maintain some state. When leaving the office at night and when returning in the morning, things are most likely as they was left (unless external events or somebody else have interfered). Third, the environment impose movement and require *proximity.* The environment filter what can be observed and activities require people to move into proximity of the artifacts and resources they need. Writing on a whiteboard require close proximity to the whiteboard and if wanting to read what is on the whiteboard, it is necessary to be in the same room as the whiteboard. As recommended by [125], *"we should look for ways of associating electronic information with physical objects in our environment."*[125]

Premise 2: Beyond interoperability

Places are full of stuff and following the last fifty years in computing, already populated with a multitude of heterogeneous systems, devices, displays, services and information sources. There is no blank canvas and Weiser's emphasis on heterogeneous devices is more important than ever. Places are already information spaces and unique ecologies and much of what is there is inherently part of local practices (see [35, 268]). Although interoperability is a pressing issue and principal to place-centric computing, we are more interested in what interoperability support. First, it should be possible to *integrate* existing infrastructure, services, systems, common devices, *and* non-computational artifacts and existing features of a place. Second, it should be possible to aggregate and *recombine* what is already there in new constellations (this is similar to the argument presented by [116]). Third, it should be possible to *extend* the capabilities of the existing environment and add computational functionality to non-computational artifacts and the physical environment.

Premise 3: Inhabitants and collocated activities

Place-centric computing indicate a shift from users and individual work to inhabitants and collocated activities. What a place affords is inherently linked to and realised through situated activities [12, 108, 138]. People are in a particular place with a purpose and intent, they engage in meaningful activities, and often in the presence of others engaged in similar and related activities (e.g. a meeting, a lecture, office work). They might be familiar strangers, colleagues and/or close friends [282]; they might be regulars or just visitors passing through. The premise in place-centric computing is that people 'on the ground' posses the knowledge to appropriate information technology in the same way they appropriate and move physical artifacts [277, 329]. First, development should happen from within and intrinsic to the local practices [193, 331]. Rogers' [302] proactive inhabitants require *local control* (see [349]) so that inhabitants are able to take an active part in setting up and evolving (and destroying) the local ubiquitous computing environment [302, p.412]. Second, place-centric computing means that the situated information space [125] *belong* to the particular place and is shared by the inhabitants.

Given that inhabitants likely have access and reason to be somewhere, the elements of the situated information space rely on *shared ownership*. Who can access, change and reconfigure particular features is determined by presence. Third, place-centric computing should support reconfigurability in the same way as existing environments do. It should be as easy to make additions and reconfigure the local information spaces as it is to move a table and/or add a chair. This require software that shifts the emphasis from *programming* environments to programming *environments* [1], or even better, construct the ubiquitous computing environment as a environment for designing places [364, cf.].

13.4 Software Medium for Place-centric Computing

With the concept *information substrates*, Klokmose et al. [201] present a conceptual break with the traditional distinction between development, authoring and use of software, and the hard distinction between applications and documents. Substrates are software entities that that *"can evolve over time and shift roles, acting as what are traditionally considered documents in one context and applications in another, or a mix of the two."* [201]. Substrates are software artifacts that are *malleable* for appropriation and personalization, *shareable* between people, and *distributable* across heterogeneous devices. Klokmose et al. present an prototype implementation of substrates with *Webstrates*. Webstrates builds upon readily available web-technology, but with a subtle change to how the web operates hereby creating a fundamentally new software medium.

In *Webstrates* a substrate (here called a webstrate) takes the form of a regular web-page, however any changes made to the web-page locally in the browser on a user's computer will persist and be seen by all other users of the same page (including changes to embedded program code). A webstrate can include tools for manipulating it self, or manipulation of a webstrate can happen through *transclusion* of a webstrate into another. The latter mechanism can create an application-document like relationship between two webstrates, where one webstrate e.g. can serve as a WYSIWYG style editor for a document webstrate. Klokmose et al. [201] demonstrate that this mechanism also allow for users to collaborate on the same document but with individually personalized editor webstrates. The code of a webstrate can be edited directly through the developer tools of a web-browser, or through a code-editor webstrate using transclusion. *Webstrates* can also serve as primarily machine readable containers of data or data channels, affording a reactive data-oriented way of developing interactive systems. In the paper Klokmose et al. demonstrate a collection of webstrates instrumented for the particular task of writing ACM style papers, hence with *Webstrates* software can become personal and idiosyncratic. With Webstrates, use, authorship and development happen in the same context inside a Web browser with no clear delineation. The relationship between use, authorship and development in *Webstrates* are therefore reminiscent of early software systems such as Smalltalk or HyperCard.

The idea of substrates (and *Webstrates*, see Implementation below) has a lot to offer place-centric computing and support a subset of the principles 'out-of-the-box'. In the present, we use it as the software infrastructure for place-centric computing, as it lessens the burden of developing content for places, provided a dynamic model for nesting with transclusion, allow situated development and transparency, as you can always inspect and change the content and functionality from within each substrate. We envision a relation where a place have a single substrate, and then through transclusion, contain substrates representing whatever is in a place, e.g. content, services, devices, and even other places – distinct ares within the place. The place substrate then becomes a way of representing and encapsulating the local information space. In a minimal design, the substrate correspond to a single place and contain substrates representing content, services and devices (see figure 13.1). In a more realistic and comprehensive setup, a place would have multiple substrates making up the local information space. Each level contains substrates that pertain to that specific scope and nested substrate representing parts of the environment. As illustrated in figure 13.1b, each level might contain a substrate per embedded devices (e.g. a desktop computer or a public display), content which can be descriptions, aggregations of services and devices, and substrates coupled with physical objects, a desk or a whiteboard.

13.5 local.here

In this section we present the proof-of-concept system *local.here*. We start by presenting the design originating in the principles of place-centric computing, followed by details of the implementation.

Design

With the design of *local.here* we express the key principles in place-centric computing as an infrastructure for ubiquitous computing environments. The design consist of three layers: A network and sensing layer used to instrument specific places, a software layer that doubles as the programming environment, and routing components implemented partly on the network components and partly in the software layer. Before exploring the technical details, we will go thought the high level design considerations.

Instrumenting places

We use two network technologies to instrument particular places, wireless local area network (WLAN) and a variation of the WiFi proximity detection technique ProxiMagic [200]. In our design we equate a distinct WLAN comprising of one or more access points as the place-specific information space. Places already have WLANs that are bound to the geographic location considering the dependency on power and cables, and the limited signal range. WLANs often follow local organisational bounds and/or indicate some sort of placial connection through the naming of the SSID (see [317]). WiFi is a familiar and well-supported infrastructure that support a wide range of personal devices, embedded systems (with the advent of Internet of Things, this will increase substantially [161]).

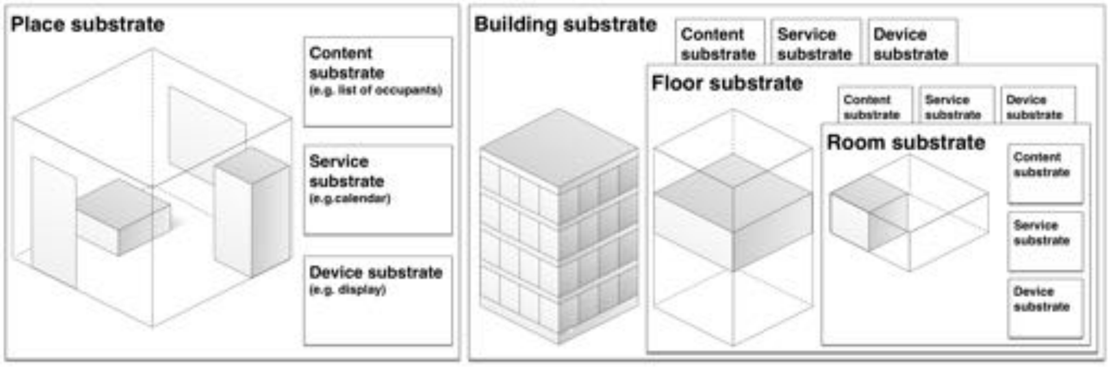

Figure 13.1: Place substrates: a) simple setup, b) nested setup

WLANs are already the backbone in ad hoc ubiquitous computing environments (see [116, 277]). Using WLAN give us two scales when instrumenting places, the top level where the WLAN itself cover the place and then one scale down to the level of each access point. This give us a scale from around 50 metres and upward to neighbourhood and city-wide networks depending on topology (e.g. [273]). In some cases this may be adequate, e.g. for a café or home (or figure 13.1a), but if we want to couple distinct areas, support the principle of nestedness and proximity, and enable the more comprehensive setup in figure 13.1b, we need a third level. *local.here* use proximity sensing nodes [200] that function in the area below 14 metres when using a single sensor, and even further down when using multiple sensors to triangulate. Unlike GPS, the WLAN is inherently bound to geographic places, by virtue of signal range and dependency on power outlets – this also means maintaining local control: The network is easily switched off or reconfigured for changing permissions.

Developing content and functionality

The software layer is based on information substrates as implemented in *Webstrates*. A part of the motivation for using webstrate is that it is browser based, meaning that *local.here* support a wide range of devices with zero-installation required by clients. More importantly, *Webstrates* is in it self a development environment, ultimately allowing inhabitants to program their environments *in* the same environment they engage in other activities[3]. In *local.here*, a place is represented by a local information space comprised by one or more webstrates. The scope of the information space is determined by the inhabitants, but generally follow the bounds of the real world, e.g. a street, building, floor or room (see figure 13.1). In *local.here* we operate with four conceptual webstrates that are associated with a place (and each nested area). The primary *local.here* represents the place and encapsulate its information space. Then we provide three types

[3] This alone addresses the challenge of programming ubiquitous computing environments discussed in [2, 81, 197, 364]

that represents various resources available within a given context. *devices.here* contain present devices, *events.here* events, and *people.here* potential information about the inhabitants. Each of these collections that can be transcluded by other webstrates – either for adding, removing and querying objects, or as a way of inspecting more detailed the available resources in the information space. It is easy to imagine a client inserting information about itself into *devices.here* or a calendar-like application drawing upon place-specific events from *events.here*. We imagine that users might insert a vCard like object into *people.here* when entering a place and then removing it again when leaving. In that sense, the conceptual webstrates may act as the extended context in context-aware computing scenarios. The basic implementation does not provide any automation or context-management, although implementing such features would be doable insofar the proactive inhabitants and the situated activities require it.

Getting into place

To achieve a working electronic place, we need a way of binding the network and the software layers together, preferably with as little configuration as possible. This also means addressing the issues of discoverability, interaction, integration and coupling. The routing layer takes care of coupling webstrates with the network-based instrumentation. The WLAN infrastructure is coupled with two webstrates, one representing the overall place, and one representing the location of the AP. The proximity sensors are coupled with a single webstrate representing whatever they are instrumenting, e.g. a small room or couches in a common area. Each AP will route any request to `.here` into the local information space. Requests to `local.here` will be routed to the place-specific webstrate representing the WLAN. The same will happen for the three other conceptual webstrates along the three levels, see figure 13.2. A request to `local.here` will, depending on the particular setup, be routed into the deepest level following the principle of nestedness. This means that `local.here` will always mean *here*, although the scope will vary depending on the local configuration. With the concept of transclution in webstrates, it is possible to just transclude e.g. `http://devices.here` within a webstrate and utilise the resource without worrying about the scope or name space. This too will be routed to the innermost webstrate containing the devices (see 13.2).

The AP is responsible for the first level of routing, the rest happen in the place-specific webstrates with a client based router. This ensures high visibility and reconfigurability on the client side and in the webstrates representing the place, instead of black-boxing the routing (and configuration) on the network, which in turn allow conditional configuration, navigation up and down the nested levels, and when needed, the ability to simply not implement full routing. We suspect that delegating too much routing to the network also means developing a centralised solution which in turn will hinder reconfigurability and control.

Each user could have their own personal top-level webstrate that always transcludes *local.here*. This could e.g. include code for providing the vCard for *people.here*, possibly with place-specific rules regarding the level of personal information shared. The virtual host name *local.here* is proposed as a generic top-level entry point into particular local

Concepts	Generic URL	Wireless LAN	Access Point	Proximity sensor
Place webstrate	http://local.here	place	area	proximity
present devices	http://devices.here	place.devices	area.devices	proximity.devices
local events	http://events.here	place.events	area.events	proximity.events
inhabitants	http://people.here	place.people	area.people	proximity.people

Figure 13.2: Coupling between conceptual elements, entry points and routing map

information spaces, supporting some standardised approach to discovery and getting into place, while also acknowledging that local information spaces will develop differently.

Implementation

Network infrastructure

The network infrastructure is made up by WLAN access point(s) and proximity sensing nodes. Each AP is configured with an open linux-based firmware[4] and runs a lightweight PHP server from USB storage. The server redirects all request to the top level domain `.here` to either specific dynamic documents or return information on the AP. Requests to `ap.here` will return a JSON object containing the MAC address of the AP and the dynamic document it is associated with. Request to `this.here` will return a JSON object with the IP and the received signal strength indication (RSSI in dBM) on the client making the request. We use an extension of ProxiMagic [200] running on a Raspberry PI Zero[5] to scan the network for clients and provide proximity data. The sensor exposes an API giving clients access to information on the proximity sensor (`<IP>\proximagic`), detected devices (`<IP>\devices`) and the client (`<IP>\this`). The two latter requests will return the IP, MAC, hostname and RSSI of either the client or all the detected devices. Instead of having a central service keeping track of all the network clients (see reference implementation in [200]), we have developed a decentralised solution that supports per sensor configuration and API. This give additional freedom in configuration and allow easy deployment. The two network components operate on two different scales with some overlap. Both distances are optimistic and depend on environmental factors.

[4] http://tomatousb.org

[5] https://www.raspberrypi.org/products/pi-zero/

Software infrastructure

The software layer for *local.here* consists of a local Webstrates server. Webstrates serve web-pages as any other web-server, however changes made in browsers to the Document Object Model (DOM) of a webstrate are made persistent on the server and synchronized to all other clients of the same page. Webstrates can be composed through transclusion using the iframe HTML element. When pages are served from the same domain and embedded in one-another using iframes, modern browsers allow scripts in the web-pages to modify the DOM of other pages across iframe boundaries. In *local.here* we use webstrates for places, user content, services (e.g. external APIs), data resources as a model object in traditional software architectural sense (e.g. `devices.here`, see figure 13.2). A user application webstrate can e.g. transclude `devices.here` and use the W3C standardized MutationObserver JavaScript API to monitor updates to its state. *Webstrates* provide a mechanism for handling user permissions on individual webstrates (i.e., read and write permissions), but this is not something we have exploited in the *local.here* prototype.

Configuration and routing

The routing mechanism orchestrates the routing between the webstrate associated with the AP and the webstrates associated with the individual proximity sensing nodes. Each component is configured on an easy removable media. The AP configuration require a firmware that support routing with Dnsmasq (`address=/here/192.168.1.1`) and running a PHP server from a USB storage. Configuring which webstrates the WLAN and AP routes to requires changing two variables in `index.php` on the removable USB drive. Configuring the proximity sensing nodes require removing the SD memory card from the Raspberry PI zero and changing the webstrate variable and setting the network information in a configuration file on the boot partition. Configuration require a SD reader and a text editor. For more advanced use, both platforms support configuration via secure shell.

When a client navigates to `local.here` on the network[6], it will be redirected to the webstrate associated with the AP through the PHP server running. From then on the routing is handled by a client-side Javascript library encapsulated in a routing webstrate that is transcluded into each place-specific webstrate. Every two seconds, the webstrate check a) if the mac address returned from `ap.here` have changed and b) the signal strength to each of the available proximity sensors. In the case that the AP has changed, the client will be redirected to the corresponding webstrate via `local.here`. In the case that the client is within proximity of a sensor (e.g. based on RSSI value), it will be redirected to the webstrate returned from querying the sensor API. These redirects

[6] Either directly in the browser on their device, or through an iframe pointing to `local.here` in their personal context webstrate.

Figure 13.3: Left: Routing pattern and the nested webstrates. Middle: Poster board user interface. Right: Poster board

are client-side redirects (i.e. setting the `window.location` with Javascript). Each of the webstrates representing the individual proxemic sensors run the same routing script to ensure that if the user moves out of proximity or into closer proximity to another sensor, a redirect will happen.

13.6 Scenarios: University research group

We illustrate and assess the aspects and capabilities of *local.here* through the development and implementation of two familiar scenarios. The first scenario illustrates a semi-public area of a university department and the coupling digital information with physical objects in the environment. The second scenario illustrates a meeting room setup combining personal computers with resources and devices present in the information space representing the meeting room. Both scenarios illustrate how mobile and personal device are used as the means of accessing and interacting with the particular instrumented place.

Scenario I: Semi-public poster board

In our research group we have a poster board containing recent papers, notifications and postings relevant to the work we do. It is situated in a corridor where students and researchers from other groups frequently pass by. We have long wanted to something more dynamic, while also keeping the physical interface of the poster board. The poster board have been instrumented with a proximity sensor and if you stand within a few metres and navigate to `local.here` you are directed into the webstrate representing the poster board. The interface contain a “Readings” section, a message board and a list with icons representing the researchers in the group and possible visitors. If a local (i.e. a member of our research group) is not present, the icon will be dimmed. It is possible to open, read and add comments to the individual PDFs and leave a message on the message board.

How it works

Instrumentation and integration is done by placing one of the proximity sensors near the poster board. This ensures a strong integration between the physical board and the local information space. Coupling content to the physical poster board is done by setting a single variable in the configuration file on the root partition on the proximity sensor. Once turned on, the proximity sensor will join the WLAN (this is also configured on the proximity sensor) and the API is then available for requests. *Discovery and routing.* Once the proximity sensor is online, it is part of the routing chain that ensures redirecting users to resources relevant to their location (see figure 13.3). When a user navigates to `local.here` they are first redirected to the webstrate representing the local information space associated with the WLAN (SSID), then the webstrate associated with the particular AP, and finally the webstrate representing the sensor within proximity of the client device. The routing functionality itself is a webstrate that is transcluded into the poster board. Thus, *discovery* is tightly couple to the particular place and the physical features.

Developing the poster board. Developing content for the poster board, or rather, decorating it, is done with a combination of custom HTML and CSS, and by transcluding content webstrates and resources. The "reading" section of the poster board is just a series of webstrates containing PDFs that are transcluded into the HTML element and the message board is essentially an editable HTML element. The element that show who is presence utilise two mechanisms in *local.here*. First, it transcludes `people.here`, which in turn redirects to `posterboard.people`. This webstrate act as a data model of who is present and the poster board. The posterboard.people webstrate are populated by the personal context running on the personal devices. This is not automated – people opt in and out, and decide how much to disclose. In the poster board scenario the members of the research group all disclose whether they are present or not, and visitors are represented anonymously. To change the content of the board, a researcher can simply go in proximity of the board with a laptop, open up the developer tools and edit the page, or alternatively use more user-friendly WYSIWYG-based content authorship webstrates to edit the board (as demonstrated in [201]).

Interaction and Shared ownership. When in front of the poster board, interacting with the poster board is just like interacting with a regular web-page. The content (DOM) is synchronised, meaning that any message added to the message board is immediately visible to other clients without the need for reloading. This support shared ownership – what is there is readily visible and content "belong" to the poster. Similarly, comments made to individual papers are only accessible by the poster board.

Scenario II: Meeting room

The second scenario is a meeting room setup similar to the common examples in the related work. The meeting room is shared among several research groups at the department, and meetings often involve outside guests and collaborators. We wanted to make the room and features more accessible for people who use it, e.g. avoid the mess with connecting various devices to the shared display. The meeting room contains a large display for presentations, a set of Philips Hue lamps and a large meeting table. The webstrate `meetingroom` contains a calendar for the meeting room, shared meeting min-

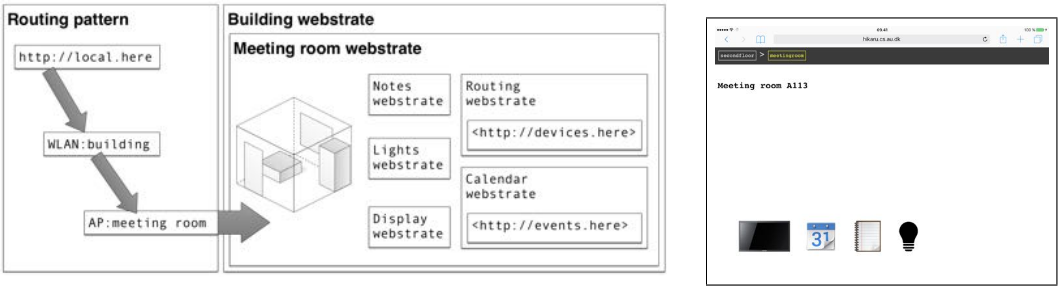

Figure 13.4: Left: Routing pattern and the nested webstrates. Right: Meeting room user interface

utes, a webstrate representing the display and a webstrate representing the light panels in the room.

How it works

Instrumentation and Discovery. In this scenario the webstrate representing the meeting room is associated with the AP in the meeting room. Given the size of the meeting room, there is no need for additional granularity. When navigating to *local.here* participants are routed to the meeting webstrate. As getting in place and discovering what the meeting room contains happens through a browser and require no knowledge of the system and its details, visitors and outsiders are able to use the system as easily as the members of the research department.

Shared resources and interaction. When in the meeting webstrate all participants can use the resources and services equally. The webstrates representing the meeting notes, calendar, large display and lights are transcluded into the meeting room webstrate. This allow everyone to change the contents of the display (without switching computer or depend on a cable), access and contribute to the share meeting notes, and control the lights. Although the meeting minutes are transcluded into the meeting room, it is also possible to open these in a separate browser window if wanting to focus on a specific task. Similarly, if one want to show the meeting minutes on the large display, the contents of the display webstrate is simply set to the URL of the meeting minutes.

Components and local resources. The calendar webstrate is a general calendar component. It can be transcluded in to any webstrate, a personal or place-specific and still provide information about place-specific events. The calendar component transcludes `events.here` and populate the calendar with the events it contain.

Interoperability, extendability and recombination. Encapsulating all the webstrates in the place-specific webstrate representing the room ensures a high degree of integration and interoperability. Setting the contents of the display works by transcluding the display webstrate into the meeting room. The display webstrate contains an iframe, and when setting the URL of the display, this change the source of the embedded iframe.

Changing the lights is possible because the transcluded webstrate representing the lights handle all the API communication to the Philips Hue bridge. When changing the color of the SVG light bulb element in the webstrate, the script makes the PUT request to the Philips Hue which then changes the value of the individual bulbs. Thus, the light webstrate maintain the state between the DOM representation (here in SVG) and the actual lamps. This effectively make the lights and display a shared resource on par with the table and whiteboard in the room. The setup support various (re)combinations of the components. For instance, the light can be configured to dim when there is content on the display or pulsate at bit when a new meeting is coming up based on the *meetingroom.events* webstrate.

13.7 Evaluation and discussion

In this section we evaluate *local.here* based on how it addresses the challenges outlined in introduction and how it relates to the premises from Place-centric computing. We evaluate and discuss the work from a systems perspective through Olsen's [274] criteria for evaluating software systems. The aim is to examine what new capabilities *local.here* offer to HCI and ubiquitous computing research.

Ubiquitous computing challenges

With `local.here` we present a possible solution to some of the core ubicomp challenges [1, 2, 197] in a way that is not based on automation or intelligent agents, and less centralised approaches, but instead by putting *end users in control* by providing them with straightforward means to instrument and decorate their places with computing.

`local.here` provides a basic discovery mechanism, that is very close in analogy to stepping into a room and taking a look around. You assume a room has a light switch, but it may also have a bookshelf or controls for the temperature — but someone has to have installed that. *Discoverability* in `local.here` is provided by coupling a substrate to the physical place, and looking in that substrate to see what the inhabitants may have installed. *Interoperability* is provided by relying on the ubiquitously web standards. Almost all IoT devices provide a RESTful interface that is easily accessible through JavaScript, a substrate created to control say a Philips Hue can be copied, shared and *adopted* for local needs. By relying on Webstrates the *development environment* and *programming framework* resides directly in the browser and the web-development literate has the tools to instrument her space ready-at-hand at all times. This offer *local.here* the possibility of focusing on programming the *environment*, rather than *programming* environments [2, 197]. The software model of *Webstrates*, however, also allows for creating authoring and development tools that would enable non-technical users to create content similar to how a decade ago WordPress[7] a decade ago provided regular people means to set up advanced customizable web blogs.

To answer the question of what is the “Hello, world!” of ubicomp? Weiser’s example of Sal’s telltale at the door could be a good candidate. With `local.here` it would be conceptually as simple as the subtrate of the telltale (which physically could be an old tablet hung on the wall) would transclude the substrate of the kitchen’s IoT coffee machine and render its state, or more advanced, look for the nearest kitchen with a machine with fresh coffee on the pot by traversing the nesting of place substrates.

The premises of Place-centric Computing

When we formulate the premises for place-centric computing, they implicitly become criteria for evaluating. How well do *local.here* adhere to the premises?

P1: Reality as the foundation

The design of and the infrastructure for *local.here* provide ample possibilities for instrumenting and follow the nested structure of exiting places. The system support multiple scopes and levels within, and the infrastructure allow a high degree of local control. The combination of infrastructure and associated place-specific webstrates as the “container” persist what is inside, while at the same time offer substantial possibilities for local continuous defining the situated information space. Finally, proximity play a very important role in *local.here*. The system emphasise that users should be there on the ground to use and participate in activities.

P2: Beyond interoperability

local.here support more than interoperability across a few devices. In the meeting room scenario we have demonstrated how the system can be used to integrate existing technologies, extend their capabilities and recombine these to support new use-cases. The scenarios illustrate how *local.here* support use-cases similar to context-aware computing, e.g. filtering based on proximity to the poster board, and integrate personal devices as way of interacting with the particular setup, as we saw in the meeting room scenario.

P3: Inhabitants and collocated activities

The focus in *local.here* is put solely on instrumenting places people are familiar with and providing an approach that take local control as a key principle and defined inhabitants as the users. We believe that the system support collocated activities, as it is possible to couple information and functionality to places, spatial features and physical objects. For

[7] `https://wordpress.org`

instance, many of the features of the poster board and meeting room scenarios become 'collocated' with the object and support collocated activities, such as a meeting.

Systems perspective

Olsen [274] outline a set of values and criteria for evaluating contributions to systems research. From the perspective of a system for developing software for place-centric computing, *local.here* inherits a number of values from *Webstrates*. In the terminology of Olsen *Webstrates* provides very *low solution viscosity* through particularly *flexibility* and *expressive leverage* [201]. A webstrate can be tinkered with at run-time, providing a high degree of support for experimentation, and at the same time strong expressive leverage as the developer does not have to worry about persisting data or synchronizing state between clients, both aspects are fundamental aspects of the medium. Olsen highlights *power in combination* as a core value and two of the principles that support this value is *simplifying interconnection* and *ease of combination*. Olsen uses the web as an example for a system that simplifies interconnection. *local.here* builds directly open the *Webstrates*-augmented web, and interconnections are as simple as creating a link or a transclusion through an iframe. Similarly on a infrastructural level interconnections between places are easily configured on the level of access points and sensing nodes. Ease of combination of services represented with webstrates can be achieved through simple client-side JavaScript. In the meeting room scenario, writing a script that matches the lighting with the background color of the webstrate presented on the large display would amount to very few lines of code. Finally, with *local.here* we aim to support Olsen's criteria of *empowering new design participants* by putting the tools for development and authorship directly in the hands of the users. Ideally *local.here* could provide the foundation for a software eco-system for place-centric ubiquitous computing allowing for end-users to decorate their places with the same ease as customizing a WordPress blog.

Limitations

The approach represented in *local.here* rely as much as possible on familiar technologies and off-the-shelf components. This means that there are room for substantial engineering and technical improvements. The quality and efficiency of the network routing mechanism and proximity sensing rely partly on how the particular network handle client handover and how the client WiFi interface respond to changes in signal quality. We have tried to address this by doing optimistic handover on the client-side, but we suspect that a large scale deployment would reveal multiple issues related to handover, routing and the network topology. One possible approach would be designing the network topology with these specific issues in mind and use related techniques, such as SNMP traps [91]. The key is to balance reconfiguration and instrumentation with optimal network design. We have completely avoided discussing security issues. There are interesting technical challenges to explore in e.g. secure proximity based access control, which we leave for future work.

A second limitation is that this work rely on the premise that a) people are interesting in the role as proactive users and b) motivated to start instrumenting and developing their local ubiquitous computing environment. We have and will continue to use *local.here* in our own environment, however, the real test is to deploy it in collaboration with people who would be interested in taking on the task implied in this work. We suspect that in-the-wild studies of this are subject to the familiar challenges of evaluating ubiquitous computing systems, yet it is something we are extremely interested in pursuing as future work.

13.8 Conclusion

In this paper we have presented an interpretation of the vision of ubiquitous computing as a place-centric vision where physical reality serves at the structure for computing, where interoperability is mediated by places, and users of computing systems are rather treated as inhabitants of computer augmented places. We have presented *local.here* as a proof of concept system that combines a WLAN based mechanism for coupling the digital and the physical with a information substrates representation of places and their content. Through examples we have shown how this enables the creation of simple place-centric software that is adapted and adaptable for the local context.

To us, the real test is if *local.here* move us forward toward Weiser's call for *electronic places*, that ensure *"the preservation of local substance and sense of place"*[295]. With *local.here* we provide the constraints to the network architecture Weiser argued was necessary, while at the same time provide the foundation for developing distinct local information spaces with a high degree of local control. If anyone is capable of preserving local substance and sense of place, it is the inhabitants.

Appendix

Bibliography

[1] Gregory D. Abowd. What next, ubicomp?: Celebrating an intellectual disappearing act. In *Proceedings of the 2012 ACM Conference on Ubiquitous Computing*, UbiComp '12, pages 31–40, New York, NY, USA, 2012. ACM. ISBN 978-1-4503-1224-0. doi: 10.1145/2370216.2370222. 24, 176, 177, 182, 191

[2] Gregory D Abowd and Elizabeth D Mynatt. Charting past, present, and future research in ubiquitous computing. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 7(1):29–58, 2000. 6, 24, 176, 177, 184, 191

[3] Mark S Ackerman, Christine A Halverson, Thomas Erickson, and Wendy A Kellogg. *Resources, co-evolution and artifacts: Theory in CSCW*. Springer Science & Business Media, 2007. 88

[4] Catherine Adams. Powerpoint, habits of mind, and classroom culture. *Journal of Curriculum studies*, 38(4):389–411, 2006. 130, 134

[5] Nicole Amare. To slideware or not to slideware: Students' experiences with powerpoint vs. lecture. *Journal of Technical Writing and Communication*, 36(3):297–308, 2006. doi: 10.2190/03GX-F1HW-VW5M-7DAR. 129, 133

[6] Richard Anderson, Ruth Anderson, Beth Simon, Steven A Wolfman, Tammy VanDeGrift, and Ken Yasuhara. Experiences with a tablet pc based lecture presentation system in computer science courses. In *ACM SIGCSE Bulletin*, volume 36, pages 56–60. ACM, 2004. 135

[7] Richard Anderson, Ruth Anderson, KM Davis, Natalie Linnell, Craig Prince, and Valentin Razmov. Supporting active learning and example based instruction with classroom technology. *ACM SIGCSE Bulletin*, 39(1):69–73, 2007. 136

[8] Richard J Anderson, Ruth Anderson, Tammy VanDeGrift, Steven Wolfman, and Ken Yasuhara. Promoting interaction in large classes with computer-mediated feedback. In *Designing for change in networked learning environments*, pages 119–123. Springer, 2003. 135

[9] Michelle Annett, Tovi Grossman, Daniel Wigdor, and George Fitzmaurice. Medusa: A proximity-aware multi-touch tabletop. In *Proceedings of the 24th*

Annual ACM Symposium on User Interface Software and Technology, UIST '11, pages 337–346, New York, NY, USA, 2011. ACM. ISBN 978-1-4503-0716-1. doi: 10.1145/2047196.2047240. 155

[10] Mahyar Arefi. Non-place and placelessness as narratives of loss: Rethinking the notion of place. *Journal of urban design*, 4(2):179–193, 1999. 28

[11] Gabriela Avram. Starting a garden, caring for it, growing with it-a study on collective practices in urban gardening. *ECSCW 2013 Adjunct Proceedings*, page 8, 2013. 87

[12] Klaus B. Bærentsen and Johan Trettvik. An activity theory approach to affordance. In *Proceedings of the Second Nordic Conference on Human-computer Interaction*, NordiCHI '02, pages 51–60, New York, NY, USA, 2002. ACM. ISBN 1-58113-616-1. doi: 10.1145/572020.572028. 3, 4, 10, 26, 27, 132, 181

[13] Matthias Baldauf, Schahram Dustdar, and Florian Rosenberg. A survey on context-aware systems. *International Journal of Ad Hoc and Ubiquitous Computing*, 2(4):263–277, 2007. 177

[14] Ellen Balka. Broadening discussion about participatory design. *Scandinavian Journal of Information Systems*, 22(1):77–84, 2010. 68, 72, 83

[15] Rafael Ballagas, Meredith Ringel, Maureen Stone, and Jan Borchers. istuff: A physical user interface toolkit for ubiquitous computing environments. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '03, pages 537–544, New York, NY, USA, 2003. ACM. ISBN 1-58113-630-7. doi: 10.1145/642611.642705. 178

[16] Till Ballendat, Nicolai Marquardt, and Saul Greenberg. Proxemic interaction: Designing for a proximity and orientation-aware environment. In *ACM International Conference on Interactive Tabletops and Surfaces*, ITS '10, pages 121–130, New York, NY, USA, 2010. ACM. ISBN 978-1-4503-0399-6. doi: 10.1145/1936652.1936676. 155, 179

[17] Guruduth Banavar and Abraham Bernstein. Software infrastructure and design challenges for ubiquitous computing applications. *Communications of the ACM*, 45(12):92–96, 2002. 177

[18] Deepak Bandyopadhyay, Ramesh Raskar, and Henry Fuchs. Dynamic shader lamps: Painting on movable objects. In *Augmented Reality, 2001. Proceedings. IEEE and ACM International Symposium on*, pages 207–216. IEEE, 2001. 152, 153

[19] Liam Bannon. From human factor to human actor. *Design at work: cooperative design of computer systems*, pages 27–44, 1991. 10, 68

[20] Liam Bannon and Susanne Bødker. Beyond the interface: Encountering artifacts in use. *DAIMI Report Series*, 18(288), 1989. 27

[21] Liam Bannon and Susanne Bødker. Constructing common information spaces. In *Proceedings of the Fifth European Conference on Computer Supported Cooperative Work*, pages 81–96. Springer, 1997. 133

[22] Liam Bannon and Kjeld Schmidt. Cscw-four characters in search of a context. *DAIMI Report Series*, 18(289), 1989. 86

[23] Jørgen Bansler. Systems development research in scandinavia: three theoretical schools. *Scandinavian journal of information systems*, 1(1):3–20, 1989. 67

[24] Miri Barak, Alberta Lipson, and Steven Lerman. Wireless laptops as means for promoting active learning in large lecture halls. *Journal of Research on Technology in Education*, 38(3):245–263, 2006. doi: 10.1080/15391523.2006.10782459. 129

[25] Maryfran Barber and David Njus. Clicker evolution: seeking intelligent design. *CBE-Life Sciences Education*, 6(1):1–8, 2007. 134, 135

[26] Jakob Bardram. Designing for the dynamics of cooperative work activities. In *Proceedings of the 1998 ACM conference on Computer supported cooperative work*, pages 89–98. ACM, 1998. 13

[27] Jakob E. Bardram and Claus Bossen. Mobility work: The spatial dimension of collaboration at a hospital. *Computer Supported Cooperative Work (CSCW)*, 14 (2):131–160, 2005. ISSN 1573-7551. doi: 10.1007/s10606-005-0989-y. 21, 26, 29, 30, 57, 154

[28] Jakob E Bardram and Claus Bossen. A web of coordinative artifacts: collaborative work at a hospital ward. In *Proceedings of the 2005 international ACM SIGGROUP conference on Supporting group work*, pages 168–176. ACM, 2005. 87

[29] Jeffrey Bardzell, Shaowen Bardzell, and Lone Koefoed Hansen. Immodest proposals: Research through design and knowledge. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, pages 2093–2102. ACM, 2015. 12

[30] Louise Barkhuus. "bring your own laptop unless you want to follow the lecture": Alternative communication in the classroom. In *Proceedings of the 2005 International ACM SIGGROUP Conference on Supporting Group Work*, GROUP '05, pages 140–143, New York, NY, USA, 2005. ACM. ISBN 1-59593-223-2. doi: 10.1145/1099203.1099230. 129, 134, 135

[31] Robert A Bartsch and Kristi M Cobern. Effectiveness of powerpoint presentations in lectures. *Computers & Education*, 41(1):77 – 86, 2003. ISSN 0360-1315. doi: 10.1016/S0360-1315(03)00027-7. 129, 133

[32] Michel Beaudouin-Lafon, Stephane Huot, Mathieu Nancel, Wendy Mackay, Emmanuel Pietriga, Romain Primet, Julie Wagner, Olivier Chapuis, Clement Pillias, James Eagan, Tony Gjerlufsen, and Clemens Klokmose. Multisurface interaction in the wild room. *Computer*, 45(4):48–56, April 2012. ISSN 0018-9162. doi: 10.1109/MC.2012.110. 152

[33] Wendy Beekes. The 'millionaire'method for encouraging participation. *Active learning in higher education*, 7(1):25–36, 2006. 134, 138

[34] Pascal Béguin. Design as a mutual learning process between users and designers. *Interacting with computers*, 15(5):709–730, 2003. 75

[35] Genevieve Bell. Making sense of museums: The museum as' cultural ecology'. *Intel Labs*, 1, 2002. 32, 34, 88, 103, 110, 181

[36] Genevieve Bell and Paul Dourish. Yesterday's tomorrows: notes on ubiquitous computing's dominant vision. *Personal and Ubiquitous Computing*, 11(2):133–143, 2007. ISSN 1617-4917. doi: 10.1007/s00779-006-0071-x. 5, 24, 28, 30, 41, 59, 177, 180

[37] Victoria ME Bellotti, Sara Cambridge, Karen Hoy, Patrick C Shih, Lisa Renery Handalian, Kyungsik Han, and John M Carroll. Towards community-centered support for peer-to-peer service exchange: rethinking the timebanking metaphor. In *Proceedings of the 32nd annual ACM conference on Human factors in computing systems*, pages 2975–2984. ACM, 2014. 87

[38] Olav W. Bertelsen. Design artefacts: towards a design-oriented epistemology. *Scandinavian Journal of Information Systems*, 12(1):2, 2000. 75

[39] Olav W. Bertelsen and Susanne Bødker. Cooperation in massively distributed information spaces. In *Proceedings of the seventh conference on European Conference on Computer Supported Cooperative Work*, pages 1–17. Kluwer Academic Publishers, 2001. 21, 26, 28, 29, 154

[40] Olav W. Bertelsen and Susanne Bødker. Interaction through multi-artifacts. In *European Conference on Cognitive Ergonomics. ECCE 11*, 2002. 57, 87

[41] Olav W. Bertelsen and Susanne Bødker. Activity theory. *HCI models, theories, and frameworks: Toward a multidisciplinary science*, pages 291–324, 2003. 26

[42] Jeremy P. Birnholtz, Carl Gutwin, and Kirstie Hawkey. Privacy in the open: How attention mediates awareness and privacy in open-plan offices. In *Proceedings of the 2007 International ACM Conference on Supporting Group Work*, GROUP '07, pages 51–60, New York, NY, USA, 2007. ACM. ISBN 978-1-59593-845-9. doi: 10.1145/1316624.1316632. 154

[43] Ole E. Bjælde, Michael E. Caspersen, Mikkel Godsk, Rikke F. Hougaard, and Annika B. Lindberg. Learning design for science teacher training and educational development. In *Proceedings of the 24th Annual Conference of the Australian Society for Computers in Learning and Tertiary Education*, volume 43, pages 21–30 (FP:9–FP:18). 2015. 131

[44] Gro Bjerknes and Tone Bratteteig. Computers—utensils or epaulets? the application perspective revisited. *AI and SOCIETY*, 2(3):258–266, 1988. 70

[45] Gro Bjerknes and Tone Bratteteig. The memoirs of two survivors: or the evaluation of a computer system for cooperative work. In *Proc. Computer Supported Cooperative Work*, pages 167–177. ACM, 1988. 70, 83

[46] Eva Bjerrum. Enabling Organisational Learning and Knowledge Sharing through Employee Involvement. Technical report, June 2010. 154, 157, 162

[47] Susanne Bødker. Through the interface. 1991. 88

[48] Susanne Bødker. Understanding representation in design. *Human-Computer Interaction*, 13(2):107–125, 1998. 75, 76

[49] Susanne Bødker. When second wave hci meets third wave challenges. In *Proceedings of the 4th Nordic conference on Human-computer interaction: changing roles*, pages 1–8. ACM, 2006. 87

[50] Susanne Bødker. Third-wave hci, 10 years later—participation and sharing. *interactions*, 22(5):24–31, 2015. 10

[51] Susanne Bødker. Using it to 'do good' in communities? *The Journal of Community Informatics*, 11(2), 2015. 107

[52] Susanne Bødker and Ellen Christiansen. Scenarios as springboards in cscw design. *Social Science, Technical Systems, and Cooperative Work: Beyond the Great Divide*, pages 217–234, 1997. 73, 74

[53] Susanne Bødker and Ellen Christiansen. Poetry in motion: appropriation of the world of apps. In *Proceedings of the 30th European conference on cognitive ergonomics*, pages 78–84. ACM, 2012. 113

[54] Susanne Bødker and Clemens Nylandsted Klokmose. The human–artifact model: An activity theoretical approach to artifact ecologies. *Human–Computer Interaction*, 26(4):315–371, 2011. 18, 88

[55] Susanne Bødker and Clemens Nylandsted Klokmose. Dynamics in artifact ecologies. In *Proceedings of the 7th Nordic Conference on Human-Computer Interaction: Making Sense Through Design*, NordiCHI '12, pages 448–457, New York, NY, USA, 2012. ACM. ISBN 978-1-4503-1482-4. doi: 10.1145/2399016.2399085. 6, 18, 32, 34, 40, 87, 88, 89, 103, 105, 106, 110, 111, 113

[56] Susanne Bødker and Anna Maria Polli. Between initial familiarity and future use: A case of collocated collaborative writing. In *COOP 2014 - Proceedings of the 11th International Conference on the Design of Cooperative Systems, 27-30 May 2014, Nice (France)*, pages 137–154, Cham, 2014. Springer International Publishing. ISBN 978-3-319-06498-7. doi: 10.1007/978-3-319-06498-7_9. 76, 119

[57] Susanne Bødker, Pelle Ehn, Joergen Knudsen, Morten Kyng, and Kim Madsen. Computer support for cooperative design. In *Proceedings of the 1988 ACM conference on Computer-supported cooperative work*, pages 377–394. ACM, 1988. 86

[58] Susanne Bødker, Kaj Grønbæk, and Morten Kyng. Cooperative design: techniques and experiences from the scandinavian scene. In *Participatory design. principles and practices*. Lawrence Erlbaum Associates, 1993. 67

[59] Susanne Bødker, Clemens Nylandsted Klokmose, Matthias Korn, and Anna Maria Polli. Participatory it in semi-public spaces. In *Proceedings of the 8th Nordic Conference on Human-Computer Interaction: Fun, Fast, Foundational*, pages 765–774. ACM, 2014. 8, 9, 43, 44, 76, 77

[60] Susanne Bødker, Kasper Hornbæk, Antti Oulasvirta, and Stuart Reeves. Nine questions for hci researchers in the making. *interactions*, 23(4):58–61, June 2016. ISSN 1072-5520. doi: 10.1145/2949686. 10

[61] Susanne Bødker, Henrik Korsgaard, and Joanna Saad-Sulonen. 'A farmer, a place and at least 20 members': The development of artifact ecologies in volunteer-based communities. In *Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing*, CSCW '16, pages 1142–1156, New York, NY, USA, 2016. ACM. ISBN 978-1-4503-3592-8. doi: 10.1145/2818048.2820029. 109, 110, 111, 114

[62] Morten Bohøj and Niels O. Bouvin. Collaborative time-based case work. In *Proc. Hypertext*, pages 141–146, New York, NY, USA, 2009. ACM. ISBN 978-1-60558-486-7. doi: 10.1145/1557914.1557940. 80

[63] Morten Bohøj, Nikolaj Gandrup Borchorst, Niels O. Bouvin, Susanne Bødker, and Pä-Ola. Zander. Timeline collaboration. In *Proc. Conference on Human Factors in Computing Systems*, pages 523–532, New York, NY, USA, 2010. ACM. ISBN 978-1-60558-929-9. doi: 10.1145/1753326.1753404. 79, 80

[64] Morten Bohøj, Niels O. Bouvin, and H. Gammelmark. A framework for interactively helpful web forms. *J. Web Eng.*, 11(1):1–22, March 2012. ISSN 1540-9589. 80

[65] Nikolaj Gandrup Borchorst and Susanne Bødker. "you probably shouldn't give them too much information"–supporting citizen-government collaboration. In

ECSCW 2011: Proceedings of the 12th European Conference on Computer Supported Cooperative Work, 24-28 September 2011, Aarhus Denmark, pages 173–192. Springer, 2011. 79, 87

[66] Claus Bossen. The parameters of common information spaces: the heterogeneity of cooperative work at a hospital ward. In *Proceedings of the 2002 ACM conference on Computer supported cooperative work*, pages 176–185. ACM, 2002. 28, 133

[67] John Bowers. The work to make a network work: Studying cscw in action. In *Proceedings of the 1994 ACM Conference on Computer Supported Cooperative Work*, CSCW '94, pages 287–298, New York, NY, USA, 1994. ACM. ISBN 0-89791-689-1. doi: 10.1145/192844.193030. 87, 106

[68] Sophie Bowlby. Friendship, co-presence and care: neglected spaces. *Social & Cultural Geography*, 12(6):605–622, 2011. doi: 10.1080/14649365.2011.601264. 3

[69] Stewart Brand. *How buildings learn: What happens after they're built.* Penguin, 1995. 4, 27, 28, 29, 30, 59

[70] Eva Brandt and Thomas Binder. Experimental design research: genealogy, intervention, argument. *International Association of Societies of Design Research, Hong Kong*, 2007. 10

[71] Eva Brandt and Camilla Grunnet. Evoking the future: Drama and props in user centered design. In *Proceedings of Participatory Design Conference (PDC 2000)*, pages 11–20, 2000. 51

[72] Tone Bratteteig. Mutual learning: enabling cooperation in systems design. In *Proc. IRIS'97*, volume 20, pages 1–20, 1997. 70, 75

[73] Harry Brignull and Yvonne Rogers. Enticing people to interact with large public displays in public spaces. In *Proceedings of INTERACT*, volume 3, pages 17–24, 2003. 2

[74] Barry Brown and Kenton O'Hara. Place as a practical concern of mobile workers. *Environment and planning A*, 35(9):1565–1587, 2003. 2, 6, 21, 22, 26, 175, 179

[75] Barry Brown and Mark Perry. Of maps and guidebooks: Designing geographical technologies. In *Proceedings of the 4th Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques*, DIS '02, pages 246–254, New York, NY, USA, 2002. ACM. ISBN 1-58113-515-7. doi: 10.1145/778712.778747. 3, 5, 176, 180

[76] J.S. Brown and P. Duguid. Borderline issues: Social and material aspects of design. *Human–Computer Interaction*, 9(1):3–36, 1994. 76

[77] Susan L. Bryant, Andrea Forte, and Amy Bruckman. Becoming wikipedian: Transformation of participation in a collaborative online encyclopedia. In *Proceedings of the 2005 International ACM SIGGROUP Conference on Supporting Group Work*, GROUP '05, pages 1–10, New York, NY, USA, 2005. ACM. ISBN 1-59593-223-2. doi: 10.1145/1099203.1099205. 87

[78] Martin Brynskov, Peter Dalsgaard, Tobias Ebsen, Jonas Fritsch, Kim Halskov, and Rune Nielsen. Staging urban interactions with media façades. In *IFIP Conference on Human-Computer Interaction*, pages 154–167. Springer, 2009. 2

[79] Martin Brynskov, JC Carvajal Bermúdez, Manu Fernández, Henrik Korsgaard, Ingrid Mulder, Katarzyna Piskorek, Lea Rekow, M Waal, et al. *Urban interaction design: towards city making.* UrbanIxD/Booksprints, 2014. 79

[80] Andrea Botero Cabrera, Anne Naukkarinen, and Joanna Saad-Sulonen. Mapping social practices through collaborative exercises and visualizations. In *Proceedings of the 5th Nordic conference on Human-computer interaction: building bridges*, pages 419–422. ACM, 2008. 90

[81] Ramon Caceres and Adrian Friday. Ubicomp systems at 20: Progress, opportunities, and challenges. *IEEE Pervasive Computing*, 11(1):14–21, 2012. 6, 24, 176, 177, 184

[82] Jane E Caldwell. Clickers in the large classroom: Current research and best-practice tips. *CBE-Life Sciences Education*, 6(1):9–20, 2007. 134

[83] Stuart K Card and Austin Henderson Jr. A multiple, virtual-workspace interface to support user task switching. *ACM SIGCHI Bulletin*, 17(SI):53–59, 1986. 18

[84] John M Carroll. Community computing as human-computer interaction. *Behaviour & Information Technology*, 20(5):307–314, 2001. 86

[85] John M Carroll and Mary Beth Rosson. Wild at home: the neighborhood as a living laboratory for hci. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 20(3):16, 2013. 106

[86] Manuel Castells. *The rise of the network society: The information age: Economy, society, and culture*, volume 1. John Wiley & Sons, 2011. 5

[87] Michel Certeau. *The Practice of Everyday Life/Michel de Certeau; translated by Steven Rendall.* Berkeley: University of California Press, 1984. 110, 111

[88] Matthew Chalmers and Areti Galani. Seamful interweaving: Heterogeneity in the theory and design of interactive systems. In *Proceedings of the 5th Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques*, DIS '04, pages 243–252, New York, NY, USA, 2004. ACM. ISBN 1-58113-787-7. doi: 10.1145/1013115.1013149. 24, 41

[89] Alphonse Chapanis. Man-machine engineering. 1965. 23

[90] Harry Chen, Tim Finin, and Anupam Joshi. An ontology for context-aware pervasive computing environments. *The knowledge engineering review*, 18(03):197–207, 2003. 177

[91] Yen-Chen Chen, Yao-Jung Chan, and Cheung-Wo She. Enabling location-based services on wireless lans. *Networks*, pages 567–572, 2003. 193

[92] Jaz Hee-jeong Choi and Eli Blevis. Hci & sustainable food culture: a design framework for engagement. In *Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries*, pages 112–117. ACM, 2010. 87

[93] Luigina Ciolfi. Space and place in digital technology research: A theoretical overview. *The SAGE Handbook of Digital Technology Research*, pages 158–173, 2013. 17, 176, 179, 180

[94] Luigina Ciolfi and Liam Bannon. *Space, Place and the Design of Technologically-Enhanced Physical Environments*, pages 217–232. Springer Netherlands, Dordrecht, 2005. ISBN 978-1-4020-3273-8. doi: 10.1007/1-4020-3273-0_15. 2, 6, 8, 17, 18, 24, 25, 26, 179

[95] Andrew Clement and Peter Van den Besselaar. A retrospective look at pd projects. *Commun. ACM*, 36(6):29–37, June 1993. ISSN 0001-0782. doi: 10.1145/153571.163264. 67

[96] Paul Cobb. The tension between theories of learning and instruction in mathematics education. *Educational psychologist*, 23(2):87–103, 1988. 131

[97] Tim Cresswell. *Place: An Introduction.* John Wiley & Sons, 2014. 17

[98] Paul Czyzewski, Jeff Johnson, and Eric Roberts. Introduction: Purpose of pdc-90. In *Proc. Conference on Participatory Design*, volume 90, 1990. 68

[99] Ole-Johan Dahl. The roots of object orientation: the simula language. In *Software pioneers*, pages 78–90. Springer, 2002. 69, 83

[100] Peter Dalsgaard. Aligning research and external stakeholder agendas in collaborative interaction design projects. In *Proceedings of the 22nd Conference of the Computer-Human Interaction Special Interest Group of Australia on Computer-Human Interaction*, pages 392–395. ACM, 2010. 11

[101] Peter Dalsgaard and Lone Koefoed Hansen. Performing perception—staging aesthetics of interaction. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 15(3):13, 2008. 2

[102] Louis Deslauriers, Ellen Schelew, and Carl Wieman. Improved learning in a large-enrollment physics class. *Science*, 332(6031):862–864, 2011. doi: 10.1126/science.1201783. 131

[103] Anind K. Dey, Gregory D. Abowd, and Daniel Salber. A conceptual framework and a toolkit for supporting the rapid prototyping of context-aware applications. *Hum.-Comput. Interact.*, 16(2):97–166, December 2001. ISSN 0737-0024. doi: 10.1207/S15327051HCI16234_02. 177

[104] Tharam Dillon, Chen Wu, and Elizabeth Chang. Cloud computing: issues and challenges. In *2010 24th IEEE international conference on advanced information networking and applications*, pages 27–33. Ieee, 2010. 5

[105] Carl DiSalvo, Phoebe Sengers, and Hrönn Brynjarsdóttir. Mapping the landscape of sustainable hci. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 1975–1984. ACM, 2010. 87

[106] Yvonne Dittrich, Sara Eriksén, and Christina Hansson. Pd in the wild; evolving practices of design in use. In *Participatory Design Conference*. CPRS (Computer Professionals for Social Responsibility), 2002. 112

[107] Alan Dix and Layda Gongora. Externalisation and design. In *Procedings of the second conference on creativity and innovation in design*, pages 31–42. ACM, 2011. 13

[108] Paul Dourish. What we talk about when we talk about context. *Personal and ubiquitous computing*, 8(1):19–30, 2004. 179, 181

[109] Paul Dourish. Re-space-ing place: "place" and "space" ten years on. In *Proceedings of the 2006 20th Anniversary Conference on Computer Supported Cooperative Work*, CSCW '06, pages 299–308, New York, NY, USA, 2006. ACM. ISBN 1-59593-249-6. doi: 10.1145/1180875.1180921. 18, 19, 41, 110, 111, 132, 179

[110] Paul Dourish and Genevieve Bell. *Divining a digital future: Mess and mythology in ubiquitous computing.* MIT Press, 2011. 6, 24, 25, 41, 62, 63, 175

[111] Paul Dourish and Victoria Bellotti. Awareness and coordination in shared workspaces. In *Proceedings of the 1992 ACM Conference on Computer-supported Cooperative Work*, CSCW '92, pages 107–114, New York, NY, USA, 1992. ACM. ISBN 0-89791-542-9. doi: 10.1145/143457.143468. 154

[112] Honglu Du, Mary Beth Rosson, John M Carroll, and Craig Ganoe. I felt like a contributing member of the class: increasing class participation with classcommons. In *Proceedings of the ACM 2009 international conference on Supporting group work*, pages 233–242. ACM, 2009. 135

[113] Robert J Dufresne, William J Gerace, William J Leonard, Jose P Mestre, and Laura Wenk. Classtalk: A classroom communication system for active learning. *Journal of computing in higher education*, 7(2):3–47, 1996. 135

[114] W Keith Edwards and Rebecca E Grinter. At home with ubiquitous computing: Seven challenges. In *International Conference on Ubiquitous Computing*, pages 256–272. Springer, 2001. 5, 177

[115] W Keith Edwards, Mark W Newman, and Jana Z Sedivy. The case for recombinant computing. *Xerox Palo Alto Research Center Technical Report CSL-01-1*, 2001. 175, 177

[116] W Keith Edwards, Mark W Newman, Jana Sedivy, Trevor Smith, and Shahram Izadi. Challenge: recombinant computing and the speakeasy approach. In *Proceedings of the 8th annual international conference on Mobile computing and networking*, pages 279–286. ACM, 2002. 28, 40, 181, 184

[117] W Keith Edwards, Mark W Newman, Jana Z Sedivy, and Trevor F Smith. Experiences with recombinant computing: Exploring ad hoc interoperability in evolving digital networks. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 16(1):3, 2009. 177

[118] Pelle Ehn and Morten Kyng. A tool perspective on design of interactive computer support for skilled workers. *DAIMI Report Series*, 14(190), 1986. 71

[119] Pelle Ehn and Morten Kyng. Cardboard computers: Mocking-it-up or hands-on the future. In *Design at work*. Lawrence Erlbaum Associates, 1991. 67, 68, 69, 71, 83

[120] Clarence A Ellis, Simon J Gibbs, and Gail Rein. Groupware: some issues and experiences. *Communications of the ACM*, 34(1):39–58, 1991. 20

[121] Yrjö Engeström. Expansive learning at work: Toward an activity theoretical reconceptualization. *Journal of education and work*, 14(1):133–156, 2001. 12, 74, 75

[122] Thomas Erickson. From interface to interplace: The spatial environment as a medium for interaction. In *European Conference on Spatial Information Theory*, pages 391–405. Springer, 1993. 18, 179

[123] Jennifer L Faust and Donald R Paulson. Active learning in the college classroom. *Journal on Excellence in College Teaching*, 9(2):3–24, 1998. 131

[124] Gerhard Fischer. Beyond hype and underestimation: identifying research challenges for the future of moocs. *Distance Education*, 35(2):149–158, 2014. doi: 10.1080/01587919.2014.920752. 130

[125] George W. Fitzmaurice. Situated information spaces and spatially aware palmtop computers. *Commun. ACM*, 36(7):39–49, July 1993. ISSN 0001-0782. doi: 10.1145/159544.159566. 8, 24, 28, 30, 57, 178, 181

[126] Geraldine Fitzpatrick. *The locales framework: understanding and designing for wicked problems*, volume 1. Springer Science & Business Media, 2003. 19, 26

[127] Christiane Floyd. A systematic look at prototyping. In *Approaches to prototyping*, pages 1–18. Springer, 1984. 74

[128] Bent Flyvbjerg. Five misunderstandings about case-study research. *Qualitative inquiry*, 12(2):219–245, 2006. 91

[129] Sean Follmer, Daniel Leithinger, Alex Olwal, Akimitsu Hogge, and Hiroshi Ishii. inform: dynamic physical affordances and constraints through shape and object actuation. In *UIST*, volume 13, pages 417–426, 2013. 152, 153

[130] Christopher Frayling. Research in art and design. 1993. 12

[131] Scott Freeman, Satch L. Eddy, Miles McDonough, Michelle K. Smith, Nnadozic Okoroafor, Hannah Jordt, and Mary Pat Wenderoth. Active learning increases student performance in science, engineering, and mathematics. 111(23):8410–8415, 2013. doi: 10.1073/pnas.1319030111. 131

[132] Eva Ganglbauer, Geraldine Fitzpatrick, Özge Subasi, and Florian Güldenpfennig. Think globally, act locally: a case study of a free food sharing community and social networking. In *Proceedings of the 17th ACM conference on Computer supported cooperative work & social computing*, pages 911–921. ACM, 2014. 86, 87

[133] Michelle Gantt and Bonnie A Nardi. Gardeners and gurus: patterns of cooperation among cad users. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 107–117. ACM, 1992. 112

[134] Bill Gaver and John Bowers. Annotated portfolios. *interactions*, 19(4):40–49, 2012. 12

[135] William Gaver. What should we expect from research through design? In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '12, pages 937–946, New York, NY, USA, 2012. ACM. ISBN 978-1-4503-1015-4. doi: 10.1145/2207676.2208538. 157

[136] William Gaver. What should we expect from research through design? In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '12, pages 937–946, New York, NY, USA, 2012. ACM. ISBN 978-1-4503-1015-4. doi: 10.1145/2207676.2208538. 10

[137] Jan Gehl. *Life between buildings: using public space*. Island Press, 2011. 3, 4, 30

[138] James Jerome Gibson. *The Ecological Approach to Visual Perception*. Psychology Press, 1986. 3, 180, 181

[139] Vicki S. Gier and David S. Kreiner. Incorporating active learning with powerpoint-based lectures using content-based questions. *Teaching of Psychology*, 36(2):134–139, 2009. doi: 10.1080/00986280902739792. 130

[140] Thomas F Gieryn. A space for place in sociology. *Annual review of sociology*, pages 463–496, 2000. 3, 17, 132, 180

[141] Erving Goffman. *Behavior in public places.* Simon and Schuster, 2008. 4

[142] Joseph A Gonzales, Casey Fiesler, and Amy Bruckman. Towards an appropriable cscw tool ecology: Lessons from the greatest international scavenger hunt the world has ever seen. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing*, pages 946–957. ACM, 2015. 87

[143] Marta C Gonzalez, Cesar A Hidalgo, and Albert-Laszlo Barabasi. Understanding individual human mobility patterns. *Nature*, 453(7196):779–782, 2008. 3

[144] David Goodman. The quality 'turn'and alternative food practices: reflections and agenda. *Journal of rural studies*, 19(1):1–7, 2003. 86

[145] Stephen Graham and Simon Marvin. *Splintering urbanism: networked infrastructures, technological mobilities and the urban condition.* Psychology Press, 2001. 2, 28

[146] Saul Greenberg. Context as a dynamic construct. *Human-Computer Interaction*, 16(2):257–268, 2001. 19

[147] Saul Greenberg. A Shape-Shifting Wall Display that Supports Individual and Group Activities. pages 1–8, April 2015. 152, 153, 170, 172

[148] Saul Greenberg and Mark Roseman. Using a room metaphor to ease transitions in groupware. *Sharing expertise: Beyond knowledge management*, pages 203–256, 2003. 3, 18, 29, 179

[149] Saul Greenberg, Nicolai Marquardt, Till Ballendat, Rob Diaz-Marino, and Miaosen Wang. Proxemic interactions: The new ubicomp? *interactions*, 18(1):42–50, 2011. ISSN 1072-5520. doi: 10.1145/1897239.1897250. 6, 24, 25, 155, 179

[150] Adam Greenfield. *Everyware: The Dawning Age of Ubiquitous Computing.* Peachpit Press, Berkeley, CA, USA, 2006. ISBN 0321384016. 24, 175

[151] Jens Emil Grønbæk, Kasper Buhl Jakobsen, Marianne Graves Petersen, Kirgegård Rasmussen, Jakob Winge, and Jeppe Stougaard. Designing for children's collective music making: How spatial orientation and configuration matter. In *Proceedings of the Nordic SIGCHI Conference on Human Factors in Computing Systems.* ACM, 2016. 155

[152] Kaj Grønbæk and Randell H. Trigg. *From Web to workplace: designing open hypermedia systems.* MIT Press, 1999. 70, 71, 73, 83

[153] Kaj Grønbæk, Jonathan. Grudin, Susanne Bødker, and Liam Bannon. *Achieving cooperative system design: shifting from a product to a process focus.* Lawrence Erlbaum Associates, Hillsdale, NJ, 1993. 68

[154] Kaj Grønbæk, Jens A. Hem, Ole L. Madsen, and Lennart Sloth. Cooperative hypermedia systems: A dexter-based architecture. *Commun. ACM*, 37(2):64–74, February 1994. ISSN 0001-0782. doi: 10.1145/175235.175240. 70

[155] Kaj Grønbæk, Morten Kyng, and Preben Mogensen. Cooperative experimental system development: Cooperative techniques beyond initial design and analysis. In *Proc. Aarhus Conference Computers in Context: Joining Forces in Design*, pages 20–29, 1995. 73

[156] Kaj Grønbæk, Peter Posselt Vestergaard, and Peter Ørbæk. Towards geo-spatial hypermedia: Concepts and prototype implementation. In *Proceedings of the thirteenth ACM conference on Hypertext and hypermedia*, pages 117–126. ACM, 2002. 178

[157] Kaj Grønbæk, Jannie F Kristensen, Peter Ørbæk, and Mette Agger Eriksen. Physical hypermedia: Organising collections of mixed physical and digital material. In *Proceedings of the fourteenth ACM conference on Hypertext and hypermedia*, pages 10–19. ACM, 2003. 178

[158] Erik Grönvall, Sofie Kinch, Marianne Graves Petersen, and Majken K. Rasmussen. Causing commotion with a shape-changing bench: Experiencing shape-changing interfaces in use. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '14, pages 2559–2568, New York, NY, USA, 2014. ACM. ISBN 978-1-4503-2473-1. doi: 10.1145/2556288.2557360. 153

[159] UTOPIA Project Group. Training, technology, and product from the quality of work perspective. Technical Report Utopia Report no 2, Swedish Center for Working Life, Stockholm, Sweden, 1981. 11, 67, 68, 69, 83

[160] Jonathan Grudin. Cscw and groupware: Their history and trajectory. *Designing Communication and Collaboration Support Systems*, 2, 1999. 68

[161] Jayavardhana Gubbi, Rajkumar Buyya, Slaven Marusic, and Marimuthu Palaniswami. Internet of things (iot): A vision, architectural elements, and future directions. *Future Generation Computer Systems*, 29(7):1645–1660, 2013. 43, 183

[162] Edward T. Hall. *The hidden dimension*, volume 1990. Anchor Books New York, 1966. 2, 3, 4, 27, 151, 155, 157, 179

[163] Edward T. Hall. Proxemics [and comments and replies]. *Current Anthropology*, 9 (2/3):83–108, 1968. ISSN 00113204, 15375382. 179, 180

[164] Kim Halskov and Nicolai B. Hansen. The diversity of participatory design research practice at pdc 2002–2012. *International Journal of Human-Computer Studies*, 74: 81–92, 2015. 72

[165] Christine A Halverson. Activity theory and distributed cognition: Or what does cscw need to do with theories? *Computer Supported Cooperative Work (CSCW)*, 11(1-2):243–267, 2002. 10, 13

[166] Christine A Halverson, Thomas Erickson, and Mark S Ackerman. Behind the help desk: evolution of a knowledge management system in a large organization. In *Proceedings of the 2004 ACM conference on Computer supported cooperative work*, pages 304–313. ACM, 2004. 86

[167] Petter Håndlykken and Kristen Nygaard. The delta system description language–motivation, main concepts and experience from use. In *Proc. Software Engineering Environments Symposium*, 1980. 69

[168] Steve Harrison and Paul Dourish. Re-place-ing space: The roles of place and space in collaborative systems. In *Proceedings of the 1996 ACM Conference on Computer Supported Cooperative Work*, CSCW '96, pages 67–76, New York, NY, USA, 1996. ACM. ISBN 0-89791-765-0. doi: 10.1145/240080.240193. 3, 18, 19, 26, 27, 28, 29, 30, 179

[169] Steve Harrison and Deborah Tatar. Places: People, events, loci – the relation of semantic frames in the construction of place. *Computer Supported Cooperative Work (CSCW)*, 17(2):97–133, 2008. ISSN 1573-7551. doi: 10.1007/s10606-007-9073-0. 179

[170] Andy Harter, Andy Hopper, Pete Steggles, Andy Ward, and Paul Webster. The anatomy of a context-aware application. *Wireless Networks*, 8(2/3):187–197, 2002. 177

[171] Christian Heath and Paul Luff. Collaborative activity and technological design: Task coordination in london underground control rooms. In *Proceedings of the Second European Conference on Computer-Supported Cooperative Work ECSCW'91*, pages 65–80. Springer, 1991. 21

[172] Christian Heath and Paul Luff. Collaboration and control: Crisis management and multimedia technology in london underground line control rooms. *Computer Supported Cooperative Work (CSCW)*, 1(1-2):69–94, 1992. 20

[173] Helene Hembrooke and Geri Gay. The laptop and the lecture: The effects of multitasking in learning environments. *Journal of Computing in Higher Education*, 15(1):46–64, 2003. ISSN 1042-1726. doi: 10.1007/BF02940852. 129, 134

[174] Austin Henderson and Morten Kyng. There's no place like home: Continuing design in use. In *Design at work*, pages 219–240. L. Erlbaum Associates Inc., 1992. 112

[175] D Austin Henderson Jr and Stuart Card. Rooms: the use of multiple virtual workspaces to reduce space contention in a window-based graphical user interface. *ACM Transactions on Graphics (TOG)*, 5(3):211–243, 1986. 3, 18, 29, 57, 58

[176] Kim J Herrmann. The impact of cooperative learning on student engagement: Results from an intervention. *Active Learning in Higher Education*, 14(3):175–187, 2013. 131

[177] Starr Roxanne Hiltz and Murray Turoff. Education goes digital: The evolution of online learning and the revolution in higher education. *Communication of the ACM*, 48(10):59–64, October 2005. ISSN 0001-0782. doi: 10.1145/1089107.1089139. 130

[178] Jason I Hong and James A Landay. An infrastructure approach to context-aware computing. *Human-Computer Interaction*, 16(2):287–303, 2001. 177

[179] Jong-yi Hong, Eui-ho Suh, and Sung-Jin Kim. Context-aware systems: A literature review and classification. *Expert Systems with Applications*, 36(4):8509–8522, 2009. 177

[180] Liisa Horelli, Joanna Saad-Sulonen, Sirkku Wallin, and Andrea Botero. When self-organization intersects with urban planning: Two cases from helsinki. *Planning Practice & Research*, 30(3):286–302, 2015. doi: 10.1080/02697459.2015.1052941. 89

[181] Elaine M Huang, Anna Koster, and Jan Borchers. Overcoming assumptions and uncovering practices: When does the public really look at public displays? In *International Conference on Pervasive Computing*, pages 228–243. Springer, 2008. 2

[182] Julie S Hui, Michael D Greenberg, and Elizabeth M Gerber. Understanding the role of community in crowdfunding work. In *Proceedings of the 17th ACM conference on Computer supported cooperative work & social computing*, pages 62–74. ACM, 2014. 87

[183] Hilary Hutchinson, Wendy Mackay, Bo Westerlund, Benjamin B Bederson, Allison Druin, Catherine Plaisant, Michel Beaudouin-Lafon, Stéphane Conversy, Helen Evans, Heiko Hansen, et al. Technology probes: inspiring design for and with families. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 17–24. ACM, 2003. 12

[184] Shamsi T. Iqbal, Jonathan Grudin, and Eric Horvitz. Peripheral computing during presentations: Perspectives on costs and preferences. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '11, pages 891–894, New York, NY, USA, 2011. ACM. ISBN 978-1-4503-0228-9. doi: 10.1145/1978942.1979073. 129

[185] Hiroshi Ishii and Brygg Ullmer. Tangible bits: towards seamless interfaces between people, bits and atoms. In *Proceedings of the ACM SIGCHI Conference on Human factors in computing systems*, pages 234–241. ACM, 1997. 24

[186] MW Jackson and MT Prosser. Less lecturing, more learning. *Studies in Higher Education*, 14(1):55–68, 1989. 131

[187] Brad Johanson, Armando Fox, and Terry Winograd. The interactive workspaces project: Experiences with ubiquitous computing rooms. *IEEE pervasive computing*, 1(2):67–74, 2002. 178

[188] Reynol Junco. Too much face and not enough books: The relationship between multiple indices of facebook use and academic performance. *Computers in Human Behavior*, 28(1):187 – 198, 2012. ISSN 0747-5632. doi: 10.1016/j.chb.2011.08.026. 134

[189] Reynol Junco. In-class multitasking and academic performance. *Computers in Human Behavior*, 28(6):2236 – 2243, 2012. ISSN 0747-5632. doi: 10.1016/j.chb.2012.06.031. 134, 147

[190] Reynol Junco and Shelia R. Cotten. No a 4 u: The relationship between multitasking and academic performance. *Computers & Education*, 59(2):505 – 514, 2012. ISSN 0360-1315. doi: 10.1016/j.compedu.2011.12.023. 130, 134, 147

[191] Heekyoung Jung, Erik Stolterman, Will Ryan, Tonya Thompson, and Marty Siegel. Toward a framework for ecologies of artifacts: How are digital artifacts interconnected within a personal life? In *Proceedings of the 5th Nordic Conference on Human-computer Interaction: Building Bridges*, NordiCHI '08, pages 201–210, New York, NY, USA, 2008. ACM. ISBN 978-1-59593-704-9. 6, 32, 34, 40, 87, 88, 90, 102, 104, 110

[192] Katrina Jungnickel and Genevieve Bell. Home is where the hub is? wireless infrastructures and the nature of domestic culture in australia. *Urban Informatics Handbook of Research on Urban Informatics: The Practice and Promise of the Real-Time City*, 2008. 43

[193] Victor Kaptelinin and Liam Bannon. Interaction design beyond the product: Creating technology-enhanced activity spaces. *Human–Computer Interaction*, 27(3): 277–309, 2012. doi: 10.1080/07370024.2011.646930. 5, 6, 8, 18, 24, 25, 26, 28, 29, 30, 31, 32, 40, 41, 62, 110, 111, 112, 125, 126, 132, 176, 177, 179, 181

[194] Victor Kaptelinin and Bonnie A Nardi. *Acting with technology: Activity theory and interaction design.* MIT press, 2006. 26

[195] Helena Karasti and Anna-Liisa Syrjänen. Artful infrastructuring in two cases of community pd. In *Proceedings of the eighth conference on Participatory design: Artful integration: interweaving media, materials and practices-Volume 1*, pages 20–30. ACM, 2004. 6, 41, 87, 107

[196] Adam Kendon. Spacing and Orientation in Co-present Interaction. In *Development of Multimodal Interfaces: Active Listening and Synchrony*, pages 1–15. Springer Berlin Heidelberg, Berlin, Heidelberg, 2010. 155, 162, 168, 169, 170

[197] Tim Kindberg and Armando Fox. System software for ubiquitous computing. *IEEE pervasive computing*, 1(1):70–81, 2002. 6, 24, 175, 176, 177, 184, 191

[198] Tim Kindberg, John Barton, Jeff Morgan, Gene Becker, Debbie Caswell, Philippe Debaty, Gita Gopal, Marcos Frid, Venky Krishnan, Howard Morris, et al. People, places, things: Web presence for the real world. *Mobile Networks and Applications*, 7(5):365–376, 2002. 178

[199] Paul A. Kirschner and Aryn C. Karpinski. Facebook® and academic performance. *Computers in Human Behavior*, 26(6):1237 – 1245, 2010. ISSN 0747-5632. doi: 10.1016/j.chb.2010.03.024. Online Interactivity: Role of Technology in Behavior Change. 130, 134

[200] Clemens N. Klokmose, Matthias Korn, and Henrik Blunck. Wifi proximity detection in mobile web applications. In *Proc. Symposium on Engineering Interactive Computing Systems*, pages 123–128, New York, NY, USA, 2014. ACM. ISBN 978-1-4503-2725-1. doi: 10.1145/2607023.2610281. 8, 77, 176, 183, 184, 186

[201] Clemens N. Klokmose, James R. Eagan, Siemen Baader, Wendy Mackay, and Michel Beaudouin-Lafon. Webstrates: Shareable dynamic media. In *Proceedings of the 28th Annual ACM Symposium on User Interface Software & Technology*, UIST '15, pages 280–290, New York, NY, USA, 2015. ACM. ISBN 978-1-4503-3779-3. doi: 10.1145/2807442.2807446. 9, 43, 175, 176, 182, 189, 193

[202] Clemens N. Klokmose, James R. Eagan, Siemen Baader, Wendy Mackay, and Michel Beaudouin-Lafon. Webstrates: Shareable dynamic media. In *Proceedings of the 28th Annual ACM Symposium on User Interface Software & Technology*, UIST '15, pages 280–290, New York, NY, USA, 2015. ACM. ISBN 978-1-4503-3779-3. doi: 10.1145/2807442.2807446. 161

[203] Clemens N Klokmose, James R Eagan, Siemen Baader, Wendy Mackay, and Michel Beaudouin-Lafon. Webstrates: Shareable dynamic media. In *Proceedings of the 28th Annual ACM Symposium on User Interface Software & Technology*, pages 280–290. ACM, 2015. 5, 52, 54

[204] Matthias Korn and Clemens Nylandsted Klokmose. Putting 'local' back into public wifi hotspots. In *Proceedings of the 2012 ACM Conference on Ubiquitous Computing*, UbiComp '12, pages 800–801, New York, NY, USA, 2012. ACM. ISBN 978-1-4503-1224-0. doi: 10.1145/2370216.2370399. 9, 149

[205] Matthias Korn, Anna Maria Polli, and Clemens Nylandsted Klokmose. Experiences from a real-time mobile collaborative writing system in an art gallery. In *Designing Mobile Face-to-Face Group Interactions at ECSCW 2013*, 2013. 8, 9, 44

[206] Henrik Korsgaard and Martin Brynskov. City bug report: Urban prototyping as participatory process and practice. In *Proceedings of the 2nd Media Architecture*

Biennale Conference: World Cities, MAB '14, pages 21–29, New York, NY, USA, 2014. ACM. ISBN 978-1-4503-3302-3. doi: 10.1145/2682884.2682896. 9, 78

[207] Henrik Korsgaard, Nicolai Brodersen Hansen, Ditte Basballe, Peter Dalsgaard, and Kim Halskov. Odenplan: A media faÇade design process. In *Proceedings of the 4th Media Architecture Biennale Conference: Participation*, MAB '12, pages 23–32, New York, NY, USA, 2012. ACM. ISBN 978-1-4503-1792-4. doi: 10.1145/2421076.2421081. 9

[208] Henrik Korsgaard, Clemens Nylandsted Klokmose, and Susanne Bødker. Computational alternatives in participatory design: Putting the t back in socio-technical research. In *Proceedings of the 14th Participatory Design Conference: Full Papers - Volume 1*, PDC '16, pages 71–79, New York, NY, USA, 2016. ACM. ISBN 978-1-4503-4046-5. doi: 10.1145/2940299.2940314. 180

[209] Ilpo Koskinen, John Zimmerman, Thomas Binder, Johan Redstrom, and Stephan Wensveen. *Design research through practice: From the lab, field, and showroom.* Elsevier, 2011. 10, 12, 13

[210] Aditi Kothiyal, Rwitajit Majumdar, Sahana Murthy, and Sridhar Iyer. Effect of think-pair-share in a large cs1 class: 83% sustained engagement. In *Proceedings of the Ninth Annual International ACM Conference on International Computing Education Research*, ICER '13, pages 137–144, New York, NY, USA, 2013. ACM. ISBN 978-1-4503-2243-0. doi: 10.1145/2493394.2493408. 130

[211] Martin Krampen. Semiotics in architecture and industrial/product design. *Design Issues*, 5(2):124–140, 1989. 26, 27, 29

[212] James M Kraushaar and David C Novak. Examining the affects of student multitasking with laptops during the lecture. *Journal of Information Systems Education*, 21(2):241, 2010. 134

[213] Stefan Kreitmayer, Yvonne Rogers, Robin Laney, and Stephen Peake. Unipad: orchestrating collaborative activities through shared tablets and an integrated wall display. In *Proceedings of the 2013 ACM international joint conference on Pervasive and ubiquitous computing*, pages 801–810. ACM, 2013. 136

[214] Klaus Krippendorff. On the essential contexts of artifacts or on the proposition that" design is making sense (of things)". *Design Issues*, pages 9–39, 1989. 87, 88

[215] Steinar Kristoffersen and Fredrik Ljungberg. "making plac" to make it work: empirical explorations of hci for mobile cscw. In *Proceedings of the international ACM SIGGROUP conference on Supporting group work*, pages 276–285. ACM, 1999. 21

[216] Peter Gall Krogh, Thomas Markussen, and Anne-Louise Bang. Ways of drifting–5 methods of experimentation in research through design. *ICoRD*, 15:39–50, 2015. 152, 157

[217] Myron W Krueger. Responsive environments. In *Proceedings of the June 13-16, 1977, national computer conference*, pages 423–433. ACM, 1977. 23, 24

[218] Myron W. Krueger. Environmental technology: Making the real world virtual. *Commun. ACM*, 36(7):36–37, July 1993. ISSN 0001-0782. doi: 10.1145/159544.159563. 23

[219] Steinar Kvale. *Doing interviews.* Sage, 2008. 91, 114, 144

[220] Morten Kyng. Making representations work. *Communications of the ACM*, 38(9): 46–55, September 1995. ISSN 0001-0782. doi: 10.1145/223248.223261. 12, 73, 74, 83

[221] Marc Langheinrich. Privacy by design—principles of privacy-aware ubiquitous systems. In *International conference on Ubiquitous Computing*, pages 273–291. Springer, 2001. 4

[222] Michael E. Lantz. The use of 'clickers' in the classroom: Teaching innovation or merely an amusing novelty? *Computers in Human Behavior*, 26(4):556 – 561, 2010. ISSN 0747-5632. doi: 10.1016/j.chb.2010.02.014. Emerging and Scripted Roles in Computer-supported Collaborative Learning. 130, 134

[223] Jean Lave and Etienne Wenger. *Situated learning: Legitimate peripheral participation.* Cambridge university press, 1991. 87

[224] Christopher A Le Dantec and Carl DiSalvo. Infrastructuring and the formation of publics in participatory design. *Social Studies of Science*, 43(2):241–264, 2013. 107

[225] Daniel Leithinger, Sean Follmer, Alex Olwal, Samuel Luescher, Akimitsu Hogge, Jinha Lee, and Hiroshi Ishii. Sublimate: State-changing virtual and physical rendering to augment interaction with shape displays. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '13, pages 1441–1450, New York, NY, USA, 2013. ACM. ISBN 978-1-4503-1899-0. doi: 10.1145/2470654.2466191. 152, 153

[226] Daniel Leithinger, Sean Follmer, Alex Olwal, and Hiroshi Ishii. Shape displays: Spatial interaction with dynamic physical form. *IEEE computer graphics and applications*, 35(5):5–11, 2015. 152, 153, 170

[227] Jay L Lemke. Across the scales of time: Artifacts, activities, and meanings in ecosocial systems. *Mind, culture, and activity*, 7(4):273–290, 2000. 4, 27, 31

[228] Gilly Leshed, Maria Håkansson, and Joseph'Jofish' Kaye. Our life is the farm and farming is our life: home-work coordination in organic farm families. In *Proceedings of the 17th ACM conference on Computer supported cooperative work & social computing*, pages 487–498. ACM, 2014. 87

[229] Youn-Kyung. Lim, Erik Stolterman, and Josh Tenenberg. The anatomy of prototypes: Prototypes as filters, prototypes as manifestations of design ideas. *Transactions on Computer-Human Interaction*, 15(2):7, 2008. 11, 13, 73, 74

[230] David Lindlbauer, Jens Emil Grønbæk, Morten Birk, Kim Halskov, Marc Alexa, and Jörg Müller. Combining Shape-Changing Interfaces and Spatial Augmented Reality Enables Extended Object Appearance. In *the 2016 CHI Conference*, pages 791–802, New York, New York, USA, 2016. ACM Press. 152, 153, 156, 165

[231] Natalie Linnell, Richard Anderson, Jim Fridley, Tom Hinckley, and Valentin Razmov. Supporting classroom discussion with technology: A case study in environmental science. In *Frontiers In Education Conference-Global Engineering: Knowledge Without Borders, Opportunities Without Passports, 2007. FIE'07. 37th Annual*, pages F1D–4. IEEE, 2007. 135, 136

[232] Paul Luff and Christian Heath. Mobility in collaboration. In *Proceedings of the 1998 ACM conference on Computer supported cooperative work - CSCW '98*, pages 305–314, New York, New York, USA, 1998. ACM Press. 20, 21, 154, 158, 170

[233] John H Lumkes. Survey of three different methods of delivering engineering content in lectures. *Journal of Educational Technology Systems*, 38(3):349–366, 2010. 134

[234] Peter Lyle, Jaz Hee-jeong Choi, and Marcus Foth. Designing for grassroots food production: an event-based urban agriculture community. In *Proceedings of the 26th Australian Computer-Human Interaction Conference on Designing Futures: the Future of Design*, pages 362–365. ACM, 2014. 109

[235] Peter Lyle, Jaz Hee-jeong Choi, and Marcus Foth. Growing food in the city: Design ideations for urban residential gardeners. In *Proceedings of the 7th International Conference on Communities and Technologies*, C&T '15, pages 89–97, New York, NY, USA, 2015. ACM. ISBN 978-1-4503-3460-0. doi: 10.1145/2768545.2768549. 87

[236] W. E. Mackay, D. S. Pagani, L. Faber, B. Inwood, P. Launiainen, L. Brenta, and V. Pouzol. Ariel: Augmenting paper engineering drawings. In *Conference Companion on Human Factors in Computing Systems*, CHI '95, pages 421–422, New York, NY, USA, 1995. ACM. ISBN 0-89791-755-3. doi: 10.1145/223355.223763. 70

[237] Wendy E. Mackay and Anne-Laure Fayard. Hci, natural science and design: A framework for triangulation across disciplines. In *Proceedings of the 2Nd Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques*, DIS '97, pages 223–234, New York, NY, USA, 1997. ACM. ISBN 0-89791-863-0. doi: 10.1145/263552.263612. 14, 15

[238] Allan MacLean, Kathleen Carter, Lennart Lövstrand, and Thomas Moran. User-tailorable systems: pressing the issues with buttons. In *Proceedings of the SIGCHI*

conference on Human factors in computing systems, pages 175–182. ACM, 1990. 40, 60, 112, 126

[239] Scott D Mainwaring, Michele F Chang, and Ken Anderson. Infrastructures and their discontents: Implications for ubicomp. In *International Conference on Ubiquitous Computing*, pages 418–432. Springer, 2004. 177

[240] Lone Malmborg, Ann Light, Geraldine Fitzpatrick, Victoria Bellotti, and Margot Brereton. Designing for sharing in local communities. In *Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems*, pages 2357–2360. ACM, 2015. 87

[241] Ezio Manzini and Rachel Coad. *Design, When Everybody Designs: An Introduction to Design for Social Innovation.* MIT Press, 2015. 87

[242] Lynne C Manzo and Douglas D Perkins. Finding common ground: The importance of place attachment to community participation and planning. *Journal of planning literature*, 20(4):335–350, 2006. 3

[243] Nicolai Marquardt, Ken Hinckley, and Saul Greenberg. Cross-device interaction via micro-mobility and f-formations. In *Proceedings of the 25th Annual ACM Symposium on User Interface Software and Technology*, UIST '12, pages 13–22, New York, NY, USA, 2012. ACM. ISBN 978-1-4503-1580-7. doi: 10.1145/2380116.2380121. 155

[244] Gary Marsden, Lucia Terrenghi, and Matt Jones. Globicomp–doing ubicomp differently: introduction to the special issue. *Personal and Ubiquitous Computing*, 15(6):551–552, 2011. 24

[245] Elizabeth J Marsh and Holli E Sink. Access to handouts of presentation slides during lecture: Consequences for learning. *Applied Cognitive Psychology*, 24(5):691–706, 2010. 134

[246] Paul Marshall, Yvonne Rogers, and Nadia Pantidi. Using F-formations to analyse spatial patterns of interaction in physical environments. In *the ACM 2011 conference*, pages 445–10, New York, New York, USA, 2011. ACM Press. 155

[247] Roberto Martinez Maldonado, Yannis Dimitriadis, Judy Kay, Kalina Yacef, and Marie-Theresa Edbauer. Orchestrating a multi-tabletop classroom: from activity design to enactment and reflection. In *Proceedings of the 2012 ACM international conference on Interactive tabletops and surfaces*, pages 119–128. ACM, 2012. 136

[248] Tara Matthews, Steve Whittaker, Hernan Badenes, and Barton Smith. Beyond end user content to collaborative knowledge mapping: Interrelations among community social tools. In *Proceedings of the 17th ACM conference on Computer supported cooperative work & social computing*, pages 900–910. ACM, 2014. 87

[249] Matts Mattsson and Stephen Kemmis. Praxis-related research: serving two masters? *Pedagogy, culture & society*, 15(2):185–214, 2007. 11

[250] Richard E. Mayer, Andrew Stull, Krista DeLeeuw, Kevin Almeroth, Bruce Bimber, Dorothy Chun, Monica Bulger, Julie Campbell, Allan Knight, and Hangjin Zhang. Clickers in college classrooms: Fostering learning with questioning methods in large lecture classes. *Contemporary Educational Psychology*, 34(1):51 – 57, 2009. ISSN 0361-476X. doi: 10.1016/j.cedpsych.2008.04.002. 130, 134

[251] John McCarthy and Luigina Ciolfi. Place as dialogue: Understanding and supporting the museum experience. *International Journal of Heritage Studies*, 14(3): 247–267, 2008. 18

[252] John McCarthy and Peter Wright. Technology as experience. *interactions*, 11(5): 42–43, 2004. 10

[253] Malcolm McCullough. *Digital Ground: Architecture, Pervasive Computing, and Environmental Knowing.* MIT Press, Cambridge, MA, USA, 2004. ISBN 0262134357. 2, 4, 6, 8, 18, 24, 25, 26, 28, 132, 176, 179, 180

[254] Sarah Mennicken and Elaine M Huang. Hacking the natural habitat: an in-the-wild study of smart homes, their development, and the people who live in them. In *International Conference on Pervasive Computing*, pages 143–160. Springer, 2012. 41

[255] Helena M Mentis, Kenton O'Hara, Abigail Sellen, and Rikin Trivedi. Interaction proxemics and image use in neurosurgery. In *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems - CHI '12*, page 927, New York, New York, USA, 2012. ACM Press. 151, 155, 156, 160, 162, 165, 172

[256] Jörn Messeter. Place-specific computing: A place-centric perspective for digital designs. *International Journal of Design*, 3(1), 2009. 6, 8, 13, 17, 18, 24, 25, 27, 30, 132, 176, 179, 180

[257] Joel Michael. Where's the evidence that active learning works? *Advances in physiology education*, 30(4):159–167, 2006. 131

[258] Sarah Kuhn Michael J. Muller and Judith A. Meskill, editors. *Proc. of Participatory Design Conference.* 1992. 71

[259] William J. Mitchell. *City of Bits: Space, Place, and the Infobahn.* Institute of Technology, 1996. ISBN 9780262631761. 5, 24

[260] Preben H. Mogensen and Susanne Wollsen. Participatory realisation?: Pd in a complex, large-scale, and commercial context. In *Proc. Participatory Design Conference*, PDC '14, pages 21–30, New York, NY, USA, 2014. ACM. ISBN 978-1-4503-2256-0. doi: 10.1145/2661435.2661443. 71, 83

[261] Cecily Morrison, Matthew Jones, Alan Blackwell, and Alain Vuylsteke. Electronic patient record use during ward rounds: a qualitative study of interaction between medical staff. *Critical Care*, 12(6):R148, 2008. 155, 156, 168

[262] Gabriel Mugar, Carsten Østerlund, Katie DeVries Hassman, Kevin Crowston, and Corey Brian Jackson. Planet hunters and seafloor explorers: legitimate peripheral participation through practice proxies in online citizen science. In *Proceedings of the 17th ACM conference on Computer supported cooperative work & social computing*, pages 109–119. ACM, 2014. 87

[263] Andreas Munk-Madsen. *Systembeskrivelse med brugere.* Datalogisk Afdeling, Aarhus Universitet, 1978. 69, 83

[264] Elizabeth D Mynatt, Vicki L O'Day, Annette Adler, and Mizuko Ito. Network communities: Something old, something new, something borrowed... *Computer Supported Cooperative Work (CSCW)*, 7(1-2):123–156, 1998. 86

[265] Aki Namioka and Douglas Schuler, editors. *Proc. of Participatory Design Conference.* 1990. 71

[266] Bonnie A Nardi. *Context and consciousness: activity theory and human-computer interaction.* MIT Press, 1996. 5, 26

[267] Bonnie A Nardi. Studying context: A comparison of activity theory, situated action models, and distributed cognition. *Context and consciousness: Activity theory and human-computer interaction*, pages 69–102, 1996. 19

[268] Bonnie A. Nardi and Vicki L. O'Day. *Information Ecologies: Using Technology with Heart.* MIT Press, Cambridge, MA, USA, 1999. ISBN 0-262-14066-7. 2, 6, 8, 18, 24, 26, 27, 32, 34, 41, 88, 103, 105, 106, 110, 181

[269] Peter Naur. Programming as theory building. *Microprocessing and microprogramming*, 15(5):253–261, 1985. 13, 14

[270] Kristen Nygaard and Olav Terje Bergo. The trade unions-new users of research. *Personnel Review*, 4(2):5–10, 1975. 69

[271] William Odom, Ron Wakkary, Youn-kyung Lim, Audrey Desjardins, Bart Hengeveld, and Richard Banks. From research prototype to research product. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, pages 2549–2561. ACM, 2016. 12

[272] Kenton O'hara, Jesper Kjeldskov, and Jeni Paay. Blended interaction spaces for distributed team collaboration. *ACM Trans. Comput.-Hum. Interact.*, 18(1):3:1–3:28, May 2011. ISSN 1073-0516. doi: 10.1145/1959022.1959025. 151, 156, 160, 162

[273] Timo Ojala, Jukka Orajärvi, Katriina Puhakka, Ilari Heikkinen, and Juhani Heikka. panoulu: Triple helix driven municipal wireless network providing open and free internet access. In *Proceedings of the 5th International Conference on Communities and Technologies*, pages 118–127. ACM, 2011. 43, 184

[274] Dan R. Olsen, Jr. Evaluating user interface systems research. In *Proceedings of the 20th Annual ACM Symposium on User Interface Software and Technology*, UIST '07, pages 251–258, New York, NY, USA, 2007. ACM. ISBN 978-1-59593-679-0. doi: 10.1145/1294211.1294256. 72, 191, 193

[275] Gary M Olson and Judith S Olson. Distance matters. *Human-computer interaction*, 15(2):139–178, 2000. 3, 20, 26

[276] Carsten S. Østerlund. Documents in place: Demarcating places for collaboration in healthcare settings. *Computer Supported Cooperative Work (CSCW)*, 17(2): 195–225, 2008. ISSN 1573-7551. doi: 10.1007/s10606-007-9064-1. 21

[277] Antti Oulasvirta. Feature when users do the ubicomp. *interactions*, 15(2):6–9, 2008. 6, 41, 59, 177, 181, 184

[278] Antti Oulasvirta and Kasper Hornbæk. Hci research as problem-solving. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, CHI '16, pages 4956–4967, New York, NY, USA, 2016. ACM. ISBN 978-1-4503-3362-7. doi: 10.1145/2858036.2858283. 10, 12, 152, 157

[279] Antti Oulasvirta and Lauri Sumari. Mobile kits and laptop trays: managing multiple devices in mobile information work. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 1127–1136. ACM, 2007. 87

[280] Antti Oulasvirta, Esko Kurvinen, and Tomi Kankainen. Understanding contexts by being there: case studies in bodystorming. *Personal and ubiquitous computing*, 7(2):125–134, 2003. 51

[281] Uta Pankoke-Babatz. Electronic behaviour settings for cscw. *AI & SOCIETY*, 14 (1):3–30, 2000. 3, 4, 19, 26

[282] Eric Paulos and Elizabeth Goodman. The familiar stranger: Anxiety, comfort, and play in public places. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '04, pages 223–230, New York, NY, USA, 2004. ACM. ISBN 1-58113-702-8. doi: 10.1145/985692.985721. 181

[283] Krista E Paulsen. Making character concrete: empirical strategies for studying place distinction. *City & Community*, 3(3):243–262, 2004. 132

[284] Peter Peltonen, Esko Kurvinen, Antti Salovaara, Giulio Jacucci, Tommi Ilmonen, John Evans, Antti Oulasvirta, and Petri Saarikko. It's mine, don't touch!: Interactions at a large multi-touch display in a city centre. In *Proceedings of the*

SIGCHI Conference on Human Factors in Computing Systems, CHI '08, pages 1285–1294, New York, NY, USA, 2008. ACM. ISBN 978-1-60558-011-1. doi: 10.1145/1357054.1357255. 154

[285] Mark Perry, Kenton O'hara, Abigail Sellen, Barry Brown, and Richard Harper. Dealing with mobility: understanding access anytime, anywhere. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 8(4):323–347, 2001. 5

[286] Sofie Pilemalm and Timpka Timpka. Third generation participatory design in health informatics – making user participation applicable to large-scale information system projects. *Journal of biomedical informatics*, 41(2):327–339, 2008. 71, 72, 83

[287] Volkmar Pipek and Volker Wulf. Infrastructuring: Toward an integrated perspective on the design and use of information technology. *Journal of the Association for Information Systems*, 10(5):447–473, 2009. 32, 87, 105, 110, 112, 123, 126

[288] Thorsten Prante, Norbert A Streitz, and Peter Tandler. Roomware: Computers disappear and interaction evolves. *Computer*, 37(12):47–54, 2004. 24

[289] Jenny Preece, Diane Maloney-Krichmar, and Chadia Abras. History of online communities. *Encyclopedia of community*, 3:1023–1027, 2003. 86

[290] Jenny Preece, Helen Sharp, and Yvonne Rogers. *Interaction Design-beyond human-computer interaction*. John Wiley & Sons, 2015. 130

[291] Michael Prince. Does active learning work? a review of the research. *JOURNAL OF ENGINEERING EDUCATION-WASHINGTON-*, 93:223–232, 2004. 131

[292] Majken K Rasmussen, Esben W Pedersen, Marianne G Petersen, and Kasper Hornbæk. Shape-changing interfaces: a review of the design space and open research questions. In *the 2012 ACM annual conference*, pages 735–744, New York, New York, USA, May 2012. ACM. 153

[293] Majken Kirkegård Rasmussen, Timothy Merritt, Miguel Bruns Alonso, and Marianne Graves Petersen. Balancing user and system control in shape-changing interfaces: A designerly exploration. In *Proceedings of the TEI '16: Tenth International Conference on Tangible, Embedded, and Embodied Interaction*, TEI '16, pages 202–210, New York, NY, USA, 2016. ACM. ISBN 978-1-4503-3582-9. doi: 10.1145/2839462.2839499. 161, 172

[294] Stuart Reeves. Human-computer interaction as science. In *Proceedings of The Fifth Decennial Aarhus Conference on Critical Alternatives*, AA '15, pages 73–84. Aarhus University Press, 2015. doi: 10.7146/aahcc.v1i1.21296. 10

[295] Vicky Reich and Mark Weiser. Libraries are more than information: situational aspects of electronic libraries. *Serials review*, 20(3):31–37, 1994. 8, 24, 25, 26, 28, 29, 30, 40, 57, 61, 62, 175, 194

[296] Edwaard C. Relph. *Place and placelessness*. Research in Planning and Design Series. Pion Limited, 1976. ISBN 9780850861112. 5, 28

[297] Henk Renting, Markus Schermer, and Ada Rossi. Building food democracy: exploring civic food networks and newly emerging forms of food citizenship. *International. Journal of Sociology of Agriculture and Food*, 19(3):289–307, 2012. 86

[298] Mike Robinson. Design for unanticipated use..... In *Proceedings of the Third European Conference on Computer-Supported Cooperative Work 13–17 September 1993, Milan, Italy ECSCW'93*, pages 187–202. Springer, 1993. 4, 57, 133

[299] Tom Rodden and Steve Benford. The evolution of buildings and implications for the design of ubiquitous domestic environments. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 9–16. ACM, 2003. 28

[300] Tom Rodden, Andy Crabtree, Terry Hemmings, Boriana Koleva, Jan Humble, Karl-Petter Åkesson, and Pär Hansson. Between the dazzle of a new building and its eventual corpse: Assembling the ubiquitous home. In *Proceedings of the 5th Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques*, DIS '04, pages 71–80, New York, NY, USA, 2004. ACM. ISBN 1-58113-787-7. doi: 10.1145/1013115.1013127. 29

[301] Yvonne Rogers. New theoretical approaches for human-computer interaction. *Annual Review of Information Science and Technology*, 38(1):87–143, 2004. 10

[302] Yvonne Rogers. *Moving on from Weiser's Vision of Calm Computing: Engaging UbiComp Experiences*, pages 404–421. Springer Berlin Heidelberg, Berlin, Heidelberg, 2006. ISBN 978-3-540-39635-2. doi: 10.1007/11853565_24. 6, 25, 26, 29, 30, 40, 61, 62, 176, 177, 181

[303] Yvonne Rogers. Hci theory: classical, modern, and contemporary. *Synthesis Lectures on Human-Centered Informatics*, 5(2):1–129, 2012. 10, 24

[304] Yvonne Rogers and Siân Lindley. Collaborating around vertical and horizontal large interactive displays: which way is best? *Interacting with Computers*, 16(6): 1133–1152, 2004. 152, 154, 168, 170, 172

[305] Mark Roseman and Saul Greenberg. Teamrooms: Network places for collaboration. In *Proceedings of the 1996 ACM Conference on Computer Supported Cooperative Work*, CSCW '96, pages 325–333, New York, NY, USA, 1996. ACM. ISBN 0-89791-765-0. doi: 10.1145/240080.240319. 18

[306] Larry D. Rosen, L. Mark Carrier, and Nancy A. Cheever. Facebook and texting made me do it: Media-induced task-switching while studying. *Computers in Human Behavior*, 29(3):948 – 958, 2013. ISSN 0747-5632. doi: 10.1016/j.chb.2012.12.001. 130, 134

[307] Chiara Rossitto, Cristian Bogdan, and Kerstin Severinson-Eklundh. Understanding constellations of technologies in use in a collaborative nomadic setting. *Computer Supported Cooperative Work (CSCW)*, 23(2):137–161, 2014. 6, 87, 88, 102, 103, 106

[308] Anne Roudaut, Abhijit Karnik, Markus Löchtefeld, and Sriram Subramanian. *Morphees: toward high shape resolution in self-actuated flexible mobile devices.* toward high "shape resolution" in self-actuated flexible mobile devices. ACM, New York, New York, USA, April 2013. 152, 153, 165

[309] Faria Sana, Tina Weston, and Nicholas J. Cepeda. Laptop multitasking hinders classroom learning for both users and nearby peers. *Computers & Education*, 62: 24 – 31, 2013. ISSN 0360-1315. doi: 10.1016/j.compedu.2012.10.003. 50, 129, 134, 137

[310] Alena Sanusi and Leysia Palen. Of coffee shops and parking lots: Considering matters of space and place in the use of public wi-fi. *Computer Supported Cooperative Work (CSCW)*, 17(2):257–273, 2008. ISSN 1573-7551. doi: 10.1007/s10606-007-9062-3. 2, 21, 22

[311] April Savoy, Robert W. Proctor, and Gavriel Salvendy. Information retention from powerpoint™ and traditional lectures. *Computers & Education*, 52(4):858 – 867, 2009. ISSN 0360-1315. doi: 10.1016/j.compedu.2008.12.005. 129, 130, 133

[312] Kjeld Schmidt. Cooperative work and its articulation: requirements for computer support. *Le travail humain*, pages 345–366, 1994. 113

[313] Kjeld Schmidt. The concept of 'work' in cscw. *Computer Supported Cooperative Work (CSCW)*, 20(4-5):341–401, 2011. 86

[314] Kjeld Schmidt and Liam Bannon. Taking cscw seriously. *Computer Supported Cooperative Work (CSCW)*, 1(1-2):7–40, 1992. 28, 133

[315] Stacey D Scott, M Sheelagh, T Carpendale, and Kori M Inkpen. Territoriality in collaborative tabletop workspaces. In *the 2004 ACM conference CSCW*, pages 294–10, New York, New York, USA, 2004. ACM Press. 152, 154, 172

[316] Neil Selwyn. The use of computer technology in university teaching and learning: a critical perspective. *Journal of Computer Assisted Learning*, 23(2):83–94, 2007. ISSN 1365-2729. doi: 10.1111/j.1365-2729.2006.00204.x. 129

[317] Suranga Seneviratne, Fangzhou Jiang, Mathieu Cunche, and Aruna Seneviratne. Ssids in the wild: Extracting semantic information from wifi ssids. In *Local Computer Networks (LCN), 2015 IEEE 40th Conference on*, pages 494–497. IEEE, 2015. 43, 183

[318] Chia Shen, Frédéric D. Vernier, Clifton Forlines, and Meredith Ringel. Diamondspin: An extensible toolkit for around-the-table interaction. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '04, pages 167–174, New York, NY, USA, 2004. ACM. ISBN 1-58113-702-8. doi: 10.1145/985692.985714. 152, 154

[319] Henrik Sørensen and Jesper Kjeldskov. Proxemic interactions with multi-artifact systems. *International Journal on Advances in Intelligent Systems*, 7(34):402–411, 2014. 155, 179

[320] Henrik Sørensen, Dimitrios Raptis, Jesper Kjeldskov, and Mikael B. Skov. The 4c framework: Principles of interaction in digital ecosystems. In *Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing*, UbiComp '14, pages 87–97, New York, NY, USA, 2014. ACM. ISBN 978-1-4503-2968-2. 87

[321] Susan Leigh Star and Karen Ruhleder. Steps towards an ecology of infrastructure: complex problems in design and access for large-scale collaborative systems. In *Proceedings of the 1994 ACM conference on Computer supported cooperative work*, pages 253–264. ACM, 1994. 87

[322] Susan Leigh Star and Karen Ruhleder. Steps toward an ecology of infrastructure: Design and access for large information spaces. *Information systems research*, 7 (1):111–134, 1996. 112

[323] Susan Leigh Star and Anselm Strauss. Layers of silence, arenas of voice: The ecology of visible and invisible work. *Computer supported cooperative work (CSCW)*, 8(1-2):9–30, 1999. 113

[324] Oliver Stickel and Thomas Ludwig. Computer supported urban gardening. In *Proceedings of the 2014 companion publication on Designing interactive systems*, pages 77–80. ACM, 2014. 87

[325] Norbert A. Streitz, Jörg Geißler, and Torsten Holmer. *Roomware for Cooperative Buildings: Integrated Design of Architectural Spaces and Information Spaces*, pages 4–21. Springer Berlin Heidelberg, Berlin, Heidelberg, 1998. ISBN 978-3-540-69706-0. 178

[326] Norbert A. Streitz, Jörg Geißler, and Torsten Holmer. Roomware for cooperative buildings: Integrated design of architectural spaces and information spaces. In *Proceedings of the First International Workshop on Cooperative Buildings, Integrating Information, Organization, and Architecture*, CoBuild '98, pages 4–21, London, UK, UK, 1998. Springer-Verlag. ISBN 3-540-64237-4. 152, 154

[327] Norbert A Streitz, Jörg Geißler, Torsten Holmer, Shin'ichi Konomi, Christian Müller-Tomfelde, Wolfgang Reischl, Petra Rexroth, Peter Seitz, and Ralf Steinmetz. i-land: an interactive landscape for creativity and innovation. In *Proceedings*

of the SIGCHI conference on Human Factors in Computing Systems, pages 120–127. ACM, 1999. 178

[328] Norbert A Streitz, Peter Tandler, Christian Müller-Tomfelde, and Shin'ichi Konomi. Roomware: Towards the next generation of human-computer interaction based on an integrated design of real and virtual worlds. *Human-Computer Interaction in the New Millenium, Addison Wesley*, pages 551–576, 2001. 24

[329] Lucy Suchman. Plans and situated actions. *New York, Cambridge University*, 1986. 181

[330] Lucy Suchman. Constituting shared workspaces. *Cognition and communication at work*, pages 35–60, 1996. 21

[331] Lucy Suchman. Located accountabilities in technology production. *Scandinavian journal of information systems*, 14(2):7, 2002. 5, 179, 181

[332] Yngve Sundblad. Bilevel display screen representation of text, graphics, and images for page make-up work. In *Proceedings of Eurographics*, volume 84, 1984. 71

[333] Anna-Liisa Syrjänen and Kari Kuutti. From system development toward work improvement: developmental work research as a potential partner method for eud. In *End-User Development*, pages 123–138. Springer, 2011. 87, 112

[334] Attila Szabo and Nigel Hastings. Using {IT} in the undergraduate classroom: should we replace the blackboard with powerpoint? *Computers & Education*, 35 (3):175 – 187, 2000. ISSN 0360-1315. doi: 10.1016/S0360-1315(00)00030-0. 129, 133

[335] Kazuki Takashima, Naohiro Aida, Hitomi Yokoyama, and Yoshifumi Kitamura. TransformTable. In *the 2013 ACM international conference*, pages 179–188, New York, New York, USA, 2013. ACM Press. 152, 153, 170

[336] Kazuki Takashima, Takafumi Oyama, Yusuke Asari, Ehud Sharlin, Saul Greenberg, and Yoshifumi Kitamura. Study and design of a shape-shifting wall display. In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems*, pages 796–806. ACM, 2016. 152, 153

[337] Emily Talen. Sense of community and neighbourhood form: An assessment of the social doctrine of new urbanism. *Urban studies*, 36(8):1361–1379, 1999. 3

[338] Maurice Ten Koppel, Gilles Bailly, Jörg Müller, and Robert Walter. Chained displays: configurations of public displays can be used to influence actor-, audience-, and passer-by behavior. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 317–326. ACM, 2012. 152, 154

[339] April R Trees and Michele H Jackson. The learning environment in clicker classrooms: student processes of learning and involvement in large university-level courses using student response systems. *Learning, Media and Technology*, 32(1): 21–40, 2007. 134

[340] Tan Minh Truong, William G Griswold, Matthew Ratto, and Susan Leigh Star. *The ActiveClass Project: Experiments in encouraging classroom participation*. Department of Computer Science and Engineering, University of California, San Diego, 2002. 135

[341] Yi-Fu Tuan. *Space and place: The perspective of experience*. U of Minnesota Press, 1977. 17

[342] Quentin Vicens and Michael E. Caspersen. Getting more scientists to revamp teaching. *Journal of College Science Teaching*, 43(5):22–27, 2014. 131

[343] Amy Voida, Zheng Yao, and Matthias Korn. (infra) structures of volunteering. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing*, pages 1704–1716. ACM, 2015. 86

[344] Stephen Voida, Matt McKeon, Christopher Le Dantec, C Forslund, Puja Verma, B McMillan, J Bunde-Pedersen, Keith Edwards, Elizabeth D Mynatt, and Ali Mazalek. inspace: Co-designing the physical and digital environment to support workplace collaboration. 2008. 178

[345] Alex Waibel, Tanja Schultz, Michael Bett, Matthias Denecke, Robert Malkin, Ivica Rogina, Rainer Stiefelhagen, and Jie Yang. Smart: The smart meeting room task at isl. In *Acoustics, Speech, and Signal Processing, 2003. Proceedings.(ICASSP'03). 2003 IEEE International Conference on*, volume 4, pages IV–752. IEEE, 2003. 178

[346] Xiaolan Wang, Ron Wakkary, Carman Neustaedter, and Audrey Desjardins. Information sharing, scheduling, and awareness in community gardening collaboration. In *Proceedings of the 7th International Conference on Communities and Technologies*, C&T '15, pages 79–88, New York, NY, USA, 2015. ACM. ISBN 978-1-4503-3460-0. doi: 10.1145/2768545.2768556. 87

[347] M.W. Wartofsky. Perception, representation, and the forms of action: Towards an historical epistemology. In *A Portrait of Twenty-five Years*, pages 215–237. Springer, 1979. 73

[348] Jenny Waycott, Sue Bennett, Gregor Kennedy, Barney Dalgarno, and Kathleen Gray. Digital divides? student and staff perceptions of information and communication technologies. *Computers & Education*, 54(4):1202 – 1211, 2010. ISSN 0360-1315. doi: 10.1016/j.compedu.2009.11.006. 129

[349] Sebastian Weise, John Hardy, Pragya Agarwal, Paul Coulton, Adrian Friday, and Mike Chiasson. Democratizing ubiquitous computing: A right for locality. In

Proceedings of the 2012 ACM Conference on Ubiquitous Computing, UbiComp '12, pages 521–530, New York, NY, USA, 2012. ACM. ISBN 978-1-4503-1224-0. doi: 10.1145/2370216.2370293. 5, 13, 30, 62, 176, 177, 181

[350] Mark Weiser. The computer for the 21st century. *Scientific american*, 265(3): 94–104, 1991. doi: 10.1038/scientificamerican0991-94. 8, 23, 24, 26, 174, 175

[351] Mark Weiser. Some computer science issues in ubiquitous computing. *Communications of the ACM*, 36(7):75–84, 1993. 24, 29, 40

[352] Mark Weiser and John Seely Brown. The coming age of calm technology. In *Beyond calculation*, pages 75–85. Springer, 1997. 23

[353] Mark Weiser, Rich Gold, and John Seely Brown. The origins of ubiquitous computing research at parc in the late 1980s. *IBM systems journal*, 38(4):693, 1999. 8

[354] Malte Weiss, Simon Voelker, Christine Sutter, and Jan Borchers. Benddesk: Dragging across the curve. In *ACM International Conference on Interactive Tabletops and Surfaces*, ITS '10, pages 1–10, New York, NY, USA, 2010. ACM. ISBN 978-1-4503-0399-6. doi: 10.1145/1936652.1936654. 152, 160

[355] Barry Wellman. Physical place and cyberplace: The rise of personalized networking. *International journal of urban and regional research*, 25(2):227–252, 2001. 5, 175

[356] Joanne I. White, Leysia Palen, and Kenneth M. Anderson. Digital mobilization in disaster response: The work & self-organization of on-line pet advocates in response to hurricane sandy. In *Proceedings of the 17th ACM Conference on Computer Supported Cooperative Work & Social Computing*, CSCW '14, pages 866–876, New York, NY, USA, 2014. ACM. ISBN 978-1-4503-2540-0. 86

[357] J. Whittle. How much participation is enough?: A comparison of six participatory design projects in terms of outcomes. In *Proc. Participatory Design Conference*, PDC '14, pages 121–130, New York, NY, USA, 2014. ACM. ISBN 978-1-4503-2256-0. doi: 10.1145/2661435.2661445. 67, 71, 72, 83

[358] Carl Wieman, Katherine Perkins, and Sarah Gilbert. Transforming science education at large research universities: A case study in progress. *Change*, 4(2):7–14, 2010. 131

[359] Daniel Wigdor, Chia Shen, Clifton Forlines, and Ravin Balakrishnan. Table-centric interactive spaces for real-time collaboration. In *Proceedings of the Working Conference on Advanced Visual Interfaces*, AVI '06, pages 103–107, New York, NY, USA, 2006. ACM. ISBN 1-59593-353-0. doi: 10.1145/1133265.1133286. 152

[360] Daniel Wigdor, Hao Jiang, Clifton Forlines, Michelle Borkin, and Chia Shen. Wespace: the design development and deployment of a walk-up and share multi-surface visual collaboration system. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 1237–1246. ACM, 2009. 178

[361] Michelle Wilkerson, William G Griswold, and Beth Simon. Ubiquitous presenter: increasing student access and control in a digital lecturing environment. In *ACM SIGCSE Bulletin*, volume 37, pages 116–120. ACM, 2005. 135, 136

[362] Raphael Wimmer, Fabian Hennecke, Florian Schulz, Sebastian Boring, Andreas Butz, and Heinrich Hußmann. Curve: Revisiting the digital desk. In *Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries*, NordiCHI '10, pages 561–570, New York, NY, USA, 2010. ACM. ISBN 978-1-60558-934-3. doi: 10.1145/1868914.1868977. 152, 160

[363] Laura R Winer and Jeremy Cooperstock. The "intelligent classroom": Changing teaching and learning with an evolving technological environment. *Computers & Education*, 38(1):253–266, 2002. 136

[364] Terry Winograd. From programming environments to environments for designing. *Commun. ACM*, 38(6):65–74, June 1995. ISSN 0001-0782. doi: 10.1145/203241.203259. 6, 19, 40, 182, 184

[365] Terry Winograd. The design of interaction. In *Beyond calculation*, pages 149–161. Springer, 1997. 132

[366] Terry Winograd. Architectures for context. *Hum.-Comput. Interact.*, 16(2):401–419, December 2001. ISSN 0737-0024. doi: 10.1207/S15327051HCI16234_18. 62

[367] Kevin Yamamoto. Banning laptops in the classroom: Is it worth the hassles? *Journal of Legal Education*, 57(4):pp. 477–520, 2007. ISSN 00222208. 130

[368] Stephen S Yau, Sandeep KS Gupta, Fariaz Karim, Sheikh I Ahamed, Yu Wang, and Bin Wang. Smart classroom: Enhancing collaborative learning using pervasive computing technology. In *ASEE 2003 Annual Conference and Exposition*, pages 13633–13642. sn, 2003. 136

[369] Steven A Yourstone, Howard S Kraye, and Gerald Albaum. Classroom questioning with immediate electronic response: Do clickers improve learning? *Decision Sciences Journal of Innovative Education*, 6(1):75–88, 2008. 134

[370] Dongsong Zhang, J. Leon Zhao, Lina Zhou, and Jay F. Nunamaker, Jr. Can e-learning replace classroom learning? *Commun. ACM*, 47(5):75–79, May 2004. ISSN 0001-0782. doi: 10.1145/986213.986216. 130

[371] Karolina M. Zielinska-Dabkowska. Critical perspectives on media architecture: Is it still possible to design projects without negatively affecting urban nighttime

environments and will the future remain dynamic, bright and multi-colored? In *Proceedings of the 2Nd Media Architecture Biennale Conference: World Cities*, MAB '14, pages 101–108, New York, NY, USA, 2014. ACM. ISBN 978-1-4503-3302-3. doi: 10.1145/2682884.2682895. 2

[372] John Zimmerman, Jodi Forlizzi, and Shelley Evenson. Research through design as a method for interaction design research in hci. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '07, pages 493–502, New York, NY, USA, 2007. ACM. ISBN 978-1-59593-593-9. doi: 10.1145/1240624.1240704. 10, 12, 13, 23

[373] John Zimmerman, Erik Stolterman, and Jodi Forlizzi. An analysis and critique of research through design: Towards a formalization of a research approach. In *Proceedings of the 8th ACM Conference on Designing Interactive Systems*, DIS '10, pages 310–319, New York, NY, USA, 2010. ACM. ISBN 978-1-4503-0103-9. doi: 10.1145/1858171.1858228. 157