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Understanding the adoption of digital whiteboard systems for collaborative design work

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Abstract

User-centered design processes are the first choice when new interactive systems or services are developed to address real customer needs and provide a good user experience. Common tools for collecting user research data, conducting brainstormings, or sketching ideas are whiteboards and sticky notes. They are ubiquitously available, and no technical or domain knowledge is necessary to use them. However, traditional pen and paper tools fall short when saving the content and sharing it with others unable to be in the same location. They are also missing further digital advantages such as searching or sorting content. Although research on digital whiteboard and sticky note applications has been conducted for over 20 years, these tools are not widely adopted in company contexts. While many research prototypes exist, they have not been used for an extended period of time in a real-world context.

The goal of this thesis is to investigate what the enablers and obstacles for the adoption of digital whiteboard systems are. As an instrument for different studies, we developed the *Tele-Board* software system for collaborative creative work. Based on interviews, observations, and findings from former research, we tried to transfer the analog way of working to the digital world. Being a software system, Tele-Board can be used with a variety of hardware and does not depend on special devices. This feature became one of the main factors for adoption on a larger scale.

In this thesis, I will present three studies on the use of Tele-Board with different user groups and foci. I will use a combination of research methods (laboratory case studies and data from field research) with the overall goal of finding out when a digital whiteboard system is used and in which cases not. Not surprisingly, the system is used and accepted if a user sees a main benefit that neither analog tools nor other applications can offer. However, I found that these perceived benefits are very different for each user and usage context. If a tool provides possibilities to use in different ways and with different equipment, the chances of its adoption by a larger group increase. Tele-Board has now been in use for over 1.5 years in a global IT company in at least five countries with a constantly growing user base. Its use, advantages, and disadvantages will be described based on 42 interviews and usage statistics from server logs. Through these insights and findings from laboratory case studies, I will present a detailed analysis of digital whiteboard use in different contexts with design implications for future systems.

Zusammenfassung

Nutzerorientierte Gestaltungsprozesse werden angewandt, um zu gewährleisten, dass neue Software für Computer und Smartphones gebrauchstauglich ist und die tatsächlichen Bedürfnisse der Anwender adressiert. Dazu sollen potentielle Anwender befragt und beobachtet und darauf basierend Ideen und Entwürfe für die neue Software entwickelt werden. Um die Nutzerdaten und Ideen zu sammeln, sowie daraus Konzepte zu erarbeiten, werden häufig Whiteboards und Haftnotizen (Post-its) benutzt. Sie haben den Vorteil, dass sie weit verbreitet sind und keine speziellen Kenntnisse erfordern. Analoge Whiteboards sowie Stift und Papier haben allerdings auch den Nachteil, dass die Informationen nicht digital gespeichert und mit Personen an anderen Standorten geteilt werden können. Auch andere digitale Vorteile, wie z. B. Inhalte suchen und sortieren, sind nicht verfügbar. Obwohl es seit 20 Jahren Forschung zu digitalen Whiteboard-Anwendungen gibt, werden diese Systeme im Firmenumfeld kaum genutzt. Diverse Forschungsprototypen sind bisher weder im Langzeiteinsatz noch in Unternehmen ausreichend getestet worden.

Ziel dieser Dissertation ist zu erforschen, welche Faktoren den Einsatz von digitalen Whiteboard-Systemen begünstigen und welche Faktoren eher hinderlich sind. Zu diesem Zweck haben wir das *Tele-Board* Software System für gemeinsames kreatives Arbeiten entwickelt. Basierend auf Interviews und Beobachtungen, sowie Erkenntnissen aus vorheriger Forschung, haben wir versucht, die analoge Arbeitsweise mit herkömmlichen Arbeitsmitteln in die digitale Welt zu übertragen. *Tele-Board* kann mit unterschiedlicher Hardware benutzt werden und ist nicht an spezielle Geräte gebunden. Diese Tatsache hat sich als Vorteil für den Einsatz der Software in größerem Umfang erwiesen.

In dieser Arbeit präsentiere ich drei Studien zur Nutzung von Tele-Board von verschiedenen Anwendern in unterschiedlichen Umgebungen. Die Studien wurden sowohl unter kontrollierten Bedingungen, als auch im realen Arbeitsumfeld durchgeführt. Wie zu erwarten war, wird das System besonders dann angenommen, wenn die Anwender Vorteile sehen, die sie mit analogen Arbeitsmitteln und anderer Software nicht haben. Allerdings unterscheiden sich die empfundenen Vorteile je nach Anwender und Nutzungskontext. Daher steigen die Chancen auf eine Verbreitung der Software, wenn sie verschiedene Anwendungsfälle und unterschiedliches Equipment unterstützt. Tele-Board ist mittlerweile seit 1,5 Jahren in einer global agierenden IT-Firma in mindestens fünf Ländern mit konstant steigenden Nutzerzahlen im Einsatz. Auf der Basis von 42 Interviews und Nutzungsstatistiken vom Server wird beschrieben, auf welche Art und Weise das System angewandt wird und welche Vor- und Nachteile es hat. Aus diesen Erkenntnissen sowie anderen Studien, präsentiere ich eine detaillierte Analyse der Nutzung von digitalen Whiteboards und gebe Empfehlungen für die Entwicklung zukünftiger Systeme.

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1. Introduction

> "Creative teams need to be able to share their thoughts not only verbally but visually and physically as well. I am not at my best writing memos. Instead, put me in a room where somebody is sketching on a whiteboard, a couple of others are writing notes on Post-its or sticking Polaroid photos on the wall, and somebody is sitting on the floor putting together a quick prototype. I haven't yet heard of a remote collaboration tool that can substitute for the give-and-take of sharing ideas in real time." Tim Brown, CEO of IDEO, 2009

Companies constantly seek to innovate. Tim Brown's book "Change by Design – How design thinking transforms organizations and inspires innovation" (Brown, 2009) is only one of numerous books that deal with the question how companies can become more innovative and creative. Most companies do not only contract design consultancies like IDEO, but want to establish creative practices within their companies. Over the last decades, several examples have shown that a focus on user needs and user-centered design methods is important for the creation of successful innovations (Buxton, 2007; Rogers et al., 2011). In the last years, *design thinking* has been promoted as an approach that can help any company to be innovative again and has been applied in companies like Procter & Gamble (Brown, 2009), Steelcase (Martin, 2009), and IBM among others (Liedtka et al., 2013).

Design thinking, like other user-centered design approaches, uses different ethnographic and design methods in order to understand users' needs and create an optimal user experience for the respective design solution. People work in interdisciplinary teams and visualize and prototype many different ideas to get quick feedback from users. For this work, they often use whiteboards and sticky notes because there is no need to learn how to work with these tools, and team members from all disciplines can easily work together (Brown, 2008). Additionally, these tools encourage quickly sketched ideas and concepts, improving communication and externalization of ideas among team members (Fallman, 2003; Klemmer et al., 2006).

Although working with traditional whiteboards and paper sticky notes has several advantages, they also have shortcomings. The greatest is the difficulty working with colleagues at remote locations. In large companies, experts for specific topics or

markets are not often available at each location, and it is difficult to involve them in a discussion on whiteboard content (Brown, 2009). For design thinking projects at Procter & Gamble, employees of different departments left their day-to-day business and worked together for three months at one location[1]. Though these projects were very successful, it is not always possible or desirable to take people from their homes and daily work. On a long term basis, companies need a way to staff projects with employees working at different locations as well. For economic and ecologic reasons, it is not possible for people to fly to other locations as often as they are needed. Besides the option to work remotely, other benefits of digital tools are particularly important in company contexts. For example, design solutions have to be presented to manager with slide decks, or the design evolution has to be documented in a digital format. Digital working materials can be saved in different versions and easily copied or sent via e-mail.

Several digital whiteboard systems have been developed and studied over the last twenty years (cf. Chapter 2.3). However, they have not been adopted on a large scale (Tang et al., 2009; Huang et al., 2006). In companies, teams use video conferencing at best, though mostly only audio conferencing is available (Tang et al., 2011). In order to share working materials, they use desktop sharing applications with limited interactivity. These tools do not allow synchronous editing from multiple people and thus it is difficult to collaborate on the same content. Furthermore, the tools do not allow workers to sketch or write ideas on sticky notes. Of course, whiteboards and sticky notes are not needed for every office task, but to apply design methods, users need digital tools that are not available today. As Brown pointed out in his quote, there is no tool that supports the methods he and other authors writing about innovative work practices promote.

This work originates in the HPI–Stanford Design Thinking Research Program, whose goal is to investigate different parts of design thinking and evaluate which factor has which influence. The basis for several studies are the educational design thinking programs at the Hasso Plattner Institute of Design at Stanford, USA (d.school)[2] and the HPI School of Design Thinking in Potsdam, Germany (D-School)[3]. They are inspired by the way of working at IDEO, where whiteboards and sticky notes are also essential working materials. Figure 1.1 shows a workspace at the D-School in Potsdam. Companies that are now adopting design thinking to improve their innovative potentials adopt these working materials along with different methods of working than before. Storytelling about user needs, quickly sketching ideas, or creating prototypes are new methods to most employees. The question is, can this way of working be adapted to the digital world? How should a system that supports this work look? Will people be able to use it in a similar way to produce similar design solutions? Furthermore, digital systems could enhance traditional methods and offer computational support for different activities not available before.

[1] The Clay Street Project: https://theclaystreetproject.pg.com, accessed on November 15, 2013
[2] http://dschool.stanford.edu/, accessed on November 15, 2013
[3] http://www.hpi.uni-potsdam.de/d_school, accessed on November 15, 2013

Figure 1.1: A workspace at the HPI School of Design Thinking in Potsdam. Is it possible to transfer this environment to the digital world?

In summary, the questions addressed in this thesis are:

- Does a digital whiteboard system support design teams during user-centered design activities in a similar way as analog tools?
- Which factors lead to the adoption of a digital whiteboard system in a corporate environment on a larger scale?
- How can an extended digital support help design teams work?

1.1 Contribution

In order to study these questions, my colleagues and I developed a system that supports design work with whiteboards and sticky notes at the same and at different locations. We observed design thinking teams working with analog tools, interviewed designers at companies, and used the tools ourselves. From this experience, we created the digital whiteboard software system *Tele-Board* as the basis for studies. In a laboratory case study, design thinking students evaluated the usability and usefulness of Tele-Board and digital whiteboard hardware. Through field research, we investigated how Tele-Board was used at a large company and which factors encouraged people to use the system. Furthermore, I created a *Synthesis Guide* to study the value of extended digital support for a particular phase of design work.

In summary, this thesis makes the following contributions:

- The concept and interaction design of *Tele-Board*, which has been used for 1.5 years in day-to-day business at a global company across three continents. At the time of writing, the system had over 400 registered users with 227 actively using it.

- The theoretical concept and implementation of a *Synthesis Guide*, which helps teams to externalize and synthesize different views on user research data.
- Two laboratory case studies that investigate the usefulness of a) Tele-Board in comparison to analog ways of working, and b) the Synthesis Guide and its structured way of synthesis compared to an unstructured way of synthesizing data.
- A field study of Tele-Board in use at a company, including 42 semi-structured interviews and usage statistics from server logs.
- Recommendations for user-centered design tools in companies and design implications for future digital whiteboard systems.

1.2 Structure of the Thesis

The remaining chapters of the thesis cover the following content:

Chapter 2: Background and Related Work This chapter introduces and compares user-centered design and design thinking. Furthermore, it presents related research on digital whiteboard systems for co-located and remote work, creativity support tools, and tools for remote collaboration in companies.

Chapter 3: Tele-Board – A Digital Whiteboard Software System This chapter introduces design thinking working modes and, derived from these, the requirements for a digital design thinking environment. Afterwards, the concept and architecture of the Tele-Board system is presented and compared to related systems.

Chapter 4: Acceptance of Digital Tools for User-Centered Design This chapter describes the first case study. It was studied how well design thinking teams, experienced with traditional tools, could accomplish a design challenge in an all-digital environment.

Chapter 5: Distributed User-Centered Design Work This chapter describes the field study of Tele-Board in use at a global company. Interviews were conducted after three months of use and after 1.5 years. An analysis of the interviews and the usage statistics shows how the system was used by teams in India, China, Italy, Germany, and the USA.

Chapter 6: Extended Digital Support This chapter first gives an overview of the theoretical concept of synthesis and summarizes the results of seven interviews with designers with different levels of experience. Afterwards, it presents the Synthesis Guide and the results of a case study evaluating it.

Chapter 7: Evaluation of Studies Based on the three studies, this chapter summarizes the main insights on the use of digital whiteboard systems. Furthermore, design implications for future systems are given.

Chapter 8: Conclusion The thesis concludes with a summary of the contributions and an outlook to future research areas.

2. Background and Related Work

In software development, as in other product development life-cycles, addressing user needs and creating a good user experience play a decisive role in the success of a new product (Grudin, 1991; Buxton, 2007; Rogers et al., 2011; Goodman et al., 2012). To create products with a well-designed user experience, a *user-centered design* approach should be pursued (Rogers et al., 2011; Kumar, 2012; Keil and Carmel, 1995). Many books and articles have been written about user-centered design processes and methods (Vredenburg et al., 2002; Mao et al., 2005). Within the last years, the term *design thinking* came to stand for innovative product development with a focus on user needs and applying methods from design disciplines. In the beginning, this chapter gives an overview of user-centered design, design thinking, and the principles and methods involved.

Design thinking and user-centered design, traditionally require many "analog" tools, such as paper, pens, sticky notes, and whiteboards – especially in the early phases of a design process (Landay and Myers, 1995; Klemmer et al., 2001). These tools foster idea sketching, prototyping, and iterative design because they are quick, easy to use, and need no special introduction (Landay and Myers, 1995; Damm et al., 2000; Buxton, 2007). However, in later phases of a design process, there is a strong need for digitization of working material and results. Either for detailed screen mockups (Landay and Myers, 1995; Klemmer et al., 2001), for slide-shows in meetings, or for sharing work with colleagues and stakeholders worldwide (Yankelovich et al., 2004; Koehne et al., 2012).

Within the last decades, a variety of whiteboard and sketching tools have been developed. They address different purposes and different phases of user-centered design. The related work presented here belongs in four categories: digital whiteboard systems for co-located use, systems that support collaboration over distances, systems that generally enhance user-centered design activities, and systems for remote collaboration in companies.

2.1 User-Centered Design and Design Thinking

The term *user-centered design* (UCD) has been coined by Donald Norman and his team in the book "User-Centered System Design: New Perspectives on Human-

Computer Interaction" (Norman and Draper, 1986). It is rather seen as a philosophy than a specific technique and encompasses various methods (Abras et al., 2004; Rogers et al., 2011). While there are different descriptions of what UCD is and how the user shall be involved, people agree that it is most important to put the focus of the design process on user needs (Rogers et al., 2011; Abras et al., 2004; Grudin, 1991). Thereby, new products should be more useful and usable.

> User-Centered Design (UCD) is a multidisciplinary design approach based on the active involvement of users to improve the understanding of user and task requirements, and the iteration of design and evaluation. It is widely considered the key to product usefulness and usability – an effective approach to overcoming the limitations of traditional system-centered design. Much has been written in the research literature about UCD. As further proof of internationally endorsed best practice, UCD processes are also defined in ISO documents [..]. Increasingly, UCD has become part of the cultural vernacular of the executives and managers who drive technology development in companies of all sizes. (Mao et al., 2005)

Another approach that puts the focus on user needs and has drawn special attention in recent times, is *design thinking* (DT). While sometimes seen as a new brand name for existing concepts and methods (Curedale, 2012), others regard it as a new, holistic way of thinking that helps to "discover new alternatives for business and society as a whole" (Brown, 2009).

2.1.1 Common Principles and Activities

The main principles of user-centered design and design thinking are very similar. For UCD they are: early focus on users and tasks, empirical measurement, and iterative design (Rogers et al., 2011). DT is regarded as a "human-centered approach to innovation" (Brown, 2009) with a "focus on people" (Curedale, 2012). Constantly iterating and evaluating concepts and prototypes are main principles as well (Curedale, 2012; Brown, 2009; Lockwood, 2009). Whereas UCD often focuses on software or web applications and their usefulness and usability (Mao et al., 2005; Kumar, 2012), DT is meant to solve more "wicked", i.e. ambiguous problems (Buchanan, 1992; Rittel, 1972) and is even seen as another way of thinking (Owen, 2007; Lockwood, 2009). DT is stressed as an "approach for creative problem solving" (Brown, 2009) for all domains, involving people from all disciplines (Lindberg et al., 2010).

For both approaches, the importance of multidisciplinary teams is paramount (Rogers et al., 2011; Brown, 2009; Curedale, 2012). This way, the skills of different disciplines as well as the different perspectives from various backgrounds are included in the idea generation and final solution (Rogers et al., 2011; Brown, 2009). Where in other approaches the product development process is divided in phases independently conducted by the design, engineering, or sales departments (Buxton, 2007), in DT or UCD, people with different backgrounds work together throughout the whole process (Buxton, 2007; Brown, 2009; Rogers et al., 2011). This way, each should empathize with the users, contribute his own ideas, and raise concerns from the beginning. This is important for a solution supported by the whole team. However, multidisciplinary team work is challenging because the working methods, priorities and technical terms among the members differ and the team must find a "common

language" on which to build their communication (Rogers et al., 2011; Brown, 2009; Plattner et al., 2009).

Another important component is the iterative nature of both approaches. Insights from user feedback as well as new ideas and findings inside the product design team lead to new perspectives possibly necessitating a change in direction for the design process. Different activities must be repeated and ideas revised (Rogers et al., 2011). Especially when teams try to create new innovations, the process is rather exploratory and involves trial and error and unexpected discoveries that force iteration (Brown, 2009; Rogers et al., 2011).

With regard to applying or implementing UCD or DT, there are many process and method descriptions for both approaches, e.g. Curedale (2012); Kumar (2012); Vredenburg et al. (2002). However, many researchers and practitioners do not agree with any process model or "recipe" (Brown, 2009), due to the unpredictable nature of an approach based on user feedback. Still, processes can make sense if they are used for didactic purposes and those new to UCD or DT (Lindberg et al., 2010). In general, it is advisable to regard all activities or methods described in the realm of these approaches as guidelines and suggestions.

As there are many descriptions of both approaches including different phases, modes or steps, it is not possible to describe one method of persuit. However, there are common activities in most descriptions of UCD and DT. In the descriptions they carry different names, and the sub-division between activities varies. Based on these, but also from my own observations, I see the following main activities.

2.1.1.1 Analyze – the problem and user needs

In the beginning, the challenge or the problem statement needs to be defined and explored. The design team "meets with key stakeholders to set the vision" (Curedale, 2012). Additionally, the team discusses how they understand the problem description and who the target users are (Rogers et al., 2011; Curedale, 2012). This phase is also called (re)framing (Lindberg et al., 2010; Kumar, 2012) as the initial problem is reframed with regard to requirements and constraints.

Afterwards, one of the most important parts of the whole approach comes into play: user research. This phase has several names: observe (Brown, 2009; Plattner et al., 2009), empathize (Stanford, 2010), know the people and context (Curedale, 2012; Kumar, 2012), grasping external knowledge (Lindberg et al., 2010), contextual inquiry (Beyer and Holtzblatt, 1998), or data gathering (Rogers et al., 2011). All of them describe similar activities, like observing users and their behaviors, conducting interviews, or using cultural probes (Beyer and Holtzblatt, 1999). For more activities or methods see Kumar (2012) and Curedale (2012).

The goal of this "Analyzing phase" is collecting a diverse and comprehensive amount of information. Thereby, the focus lies on qualitative research, opposed to quantitative market research. The design team engages with a few users with complementary backgrounds and experiences or even extreme users as their feedback can lead to very valuable insights (Curedale, 2012; Brown, 2009).

2.1.1.2 Synthesize / Consolidate

After collecting a large amount of information through different methods, the information is synthesized or consolidated to define the team's point of view (Stanford,

2010; Plattner et al., 2009). First, the team members compile what they have learned from user research. Typically this "knowledge pooling" (Lindberg et al., 2010) is done with the help of "storytelling" (Quesenbery and Brooks, 2010; Brown, 2009). Through storytelling, team members present what they have learned from interviews and observations in an empathic way that conveys the user's experiences and feelings. While one person presents, the others take notes. This way, all information considered important is recorded and can be used further-on.

Then, the design team synthesizes the information to make sense of it (Brown, 2009). This process is also called "framing" (Hey et al., 2008; Curedale, 2012) as the most important information should be framed here. Usually, the team starts to cluster the pieces of information they have written during storytelling to find similarities and differences in the user research data (cf. Hinman (2011)). There are still other methods and frameworks that can be used for converging the large amounts of data, see Kolko (2011); Kumar (2012); Curedale (2012) for examples. Researchers agree that this part is difficult but very important for the whole design process (Kolko, 2011; Brown, 2009). See Chapter 6 for a detailed description of synthesis and the difficulties it presents for design teams.

2.1.1.3 Ideate

Through synthesis, the team has created insights from the user research data. Sometimes, they formulate one sentence as their "point of view" on users' needs. The insights or the "point of view" is the basis for ideating. Brown and Wyatt (2010) define "ideation as the process of generating, developing, and testing ideas" , others see the focus of this phase mainly in the generation of ideas (Stanford, 2010; Lindberg et al., 2010; Curedale, 2012), which is followed by and closely interlinked with prototyping and testing.

Researchers and practitioners agree it is important to generate as many ideas as possible in the first place (Rogers et al., 2011; Brown and Wyatt, 2010; Lindberg et al., 2010), and several brainstorming techniques have been developed for fostering the creation of ideas (Curedale, 2012; Gray et al., 2010). How the ideation process takes place in detail also depends on the participants and their relationship. Researchers have found out that a group brainstorming does not necessarily lead to the production of many ideas because cultural, social, and technological factors may strongly influence the outcome (Wang et al., 2010; Hilliges et al., 2007; Geyer et al., 2012). Several "brainstorming rules" that should facilitate a successful brainstorming have been proposed (Kelley, 2002; Rogers et al., 2011). Important rules are: include participants with multidisciplinary backgrounds and a range of experiences, defer initial judgment on the ideas because unconventional ideas have much potential, encourage "being visual", i.e. sketching ideas and drawing diagrams in order to illustrate the idea and facilitate recall (Brown, 2009; Kelley, 2002). See also Chapter 2.3.3 on research how to support ideation.

2.1.1.4 Prototype and Test

As previously explained, there is a smooth transition between ideation, prototyping, and testing. The sketch of an idea can be seen as a low-fidelity paper prototype and gathering the team's feedback as a first test. Prototypes can have different characteristics and purposes (Rhinow et al., 2012). They can be made of paper or

Lego bricks, be a digital click-through prototype, or even a role-play to convey an experience. They can help within the team to develop a concept, or they can be the basis for testing with users and collecting their feedback (Rhinow et al., 2012; Rogers et al., 2011). No matter at which stage of the design process, prototypes are the basis for evaluating the present concept, and it is important to do this several times (Brown, 2009). Dow et al. (2009) could show that teams who tested and refined their prototypes several times outperformed teams who spent their time on only one design. For more details and examples on prototyping and testing, see Kumar (2012); Warfel (2009); Beyer and Holtzblatt (1998).

2.1.2 Common Tools and Artifacts

In order to perform the activities described above, teams use different working materials and tools. Especially in the beginning of a project, these are typically low-fidelity office products, like pens and paper. Ideally, teams have their own "project space" where they can collect all of their information and make them visible on walls and whiteboards (Covi et al., 1998). Particularly for analyzing and consolidating the data from user research, it is important to make the information visible and tangible (Hinman, 2011). A common tool teams frequently use for capturing this kind of information is sticky notes (Brown, 2009; Hinman, 2011; Curtis et al., 1999; Beyer and Holtzblatt, 1998). Also during the ideation phase, sticky notes serve as idea collection and discussion tools (Klemmer et al., 2001; Brown, 2009). On one hand, sticky notes have the advantage that they force people to create concise chunks of information, formulated in a few words or drawings. On the other hand, it is possible to move the notes around easily, allowing teams to create meaningful structures together (Brown, 2009; Hinman, 2011). Sticky notes' flexible nature allow people to use them in whatever way they need, including as structural elements (Gray et al., 2010).

Sticky notes reveal their full potential in connection with whiteboards. Whiteboards are large public workplaces where information is visible and accessible to everyone (Teasley et al., 2000; Klemmer et al., 2001; Covi et al., 1998). In general, they have become the main tool for informal office work (Tang et al., 2009; Mynatt et al., 1999). Especially for UCD practices, whiteboards are important because they support teamwork and can be used flexibly. While standing in front of a whiteboard, the whole team can work together at the same space. Whiteboards can be used for displaying and consolidating user research data, for collecting ideas and for visualizing concepts and prototypes.

In addition to whiteboards and sticky notes, design teams sometimes use different kinds of "prototyping material". Although a variety of prototypes can already be created with the help of whiteboards, sticky notes and pens (e.g. interactive paper-prototypes (Buxton, 2007)), other craft supplies such as fabric, plasticine, or legos encourage teams to quickly try out different ideas (Brown, 2009).

2.2 Potential Advantages and Disadvantages of Digital Tools

Design teams often use analog working materials and tools. The analog way of working has several advantages and is preferred by the majority of users (Landay

and Myers, 1995; Klemmer et al., 2008; Cook and Bailey, 2005). Everybody immediately knows how to use pens, paper, and whiteboards without training or special knowledge. Pen and paper are almost always available, they do not run out of power or have a missing internet connection. They are cheap, portable, tangible, and it is easier to read on screens than on displays (Wellner, 1993; Cook and Bailey, 2005). If information is outlined on whiteboards or walls, members have a good overview (Klemmer et al., 2001). To switch between seeing details or all information at a glance, users only need to get closer to or further away from the whiteboard. Paper sticky notes can be easily rearranged and structured, supporting collaboration in design teams (Brown, 2009; Klemmer et al., 2001).

However, analog ways of working also have disadvantages, especially in companies, where the outcome must be presented in a digital format most of the time. The transition from paper to digital is perceived as quite problematic (Klemmer et al., 2001; Wellner, 1993). Furthermore, if sticky notes are moved or whiteboard strokes erased, there is no longer the possibility to see how it was before. Probably the biggest disadvantage of working with paper and traditional whiteboards is that it excludes co-workers at other locations (Klemmer et al., 2001; Whittaker and Schwarz, 1995). To work together, the team has to be at one location. If team members are ill, in their home-office, or located in another country, they cannot participate in the activities described above.

With the help of digital tools, these problems could be resolved. All information could be archived and retrieved at any time. Information could be easily copied, shared with other people and searched (Wellner, 1993). Besides these advantages that also improve co-located work, digital tools could enable remote work. If working materials are digital, they can be manipulated from any location with internet access. Furthermore, digital tools could also support specific user-centered design activities. For example, they could foster idea generation or help users to synthesize information from user research.

In line with the advantages of analog tools, researchers have reported the disadvantages of digital tools for user-centered design. Digital tools generally do not allow for uncomplicated sketching and quick iterations (Landay and Myers, 1995; Buxton, 2007) because they are not immediately available (Lin et al., 2004). Several tools cannot be used as flexibly as whiteboards and sticky notes (Hinman, 2011). For example they force users to specify too many details when they want to create a low-fidelity prototype (Landay and Myers, 1995). With standard desktop tools, users are also bound to small displays instead of working at life-sized whiteboards that make the content permanently visible.

These disadvantages are general drawbacks that can arise when the analog way of working of UCD or DT is transferred to the digital world. However, several research projects have tried to overcome these obstacles.

2.3 Related Work

The related work focuses on digital whiteboard and sticky note systems. Some of them are intended for co-located whiteboard use, others for remote work. There are also tools that offer special support for some activities like ideation. Furthermore, I will give an overview of tools used for remote collaboration in companies.

2.3.1 Digital Whiteboard and Sticky Note Tools for Co-located Teams

Liveboard was the first interactive whiteboard system for computer-supported meetings (Elrod et al., 1992). Unlike other meeting systems (e.g. the *Colab Project* (Stefik et al., 1987)), it enabled direct, stylus-based input at a large-area display. To allow this, the researchers not only developed a whiteboard software application but also the whole hardware setup for pen input. *Tivoli* (Pedersen et al., 1993) was a more advanced whiteboard application that ran on Liveboard. The authors "strived to provide its users with the simplicity, facile use, and easily understood functions of conventional whiteboards [..]" (Pedersen et al., 1993) and introduced interaction design characteristics for large displays, multitouch, and gesture input. Another whiteboard application that used the Liveboard hardware was the *DOLPHIN* system (Streitz et al., 1994). It was introduced for co-located meetings in corporate environments but could also connect with remote users or meeting rooms. The whiteboard application offered similar functions as Tivoli and additionally users could add images and "hypermedia notes" that can be seen as the digital precursors to sticky notes. Based on DOLPHIN, Streitz et al. (1999) presented the *i-LAND* environment as their vision of a future workspace. The environment included an interactive wall, an interactive table and two chairs that allowed for personal input. This way, the authors envisioned a fully digital "project space" just like a normal project room (Covi et al., 1998).

The goal of the aforementioned systems was to enable whiteboard use in meetings. The whiteboard interface *Flatland* (Mynatt et al., 1999) focused on supporting informal whiteboard work inside offices. The Flatland software was supposed to run on interactive whiteboard hardware, such as a SmartBoard (see Chapter 3.3.3 for more details). Based on the authors' observations of whiteboard use, the software proposed special assistance for different tasks as well as mechanisms for managing space on the whiteboard and creating a history function.

The *NoteCards* environment (Halasz et al., 1987) was one of the first systems that was designed to "help people work with ideas". It gave the possibility to structure and arrange ideas in the form of networks or mindmaps. A system that combined a whiteboard application and sticky notes was the *Designers' Outpost* (Klemmer et al., 2001) for collaborative web site design. In this system, users could work with physical sticky notes that were captured by a special camera setup (front and rear camera) and digitized. The authors also included special functions like the automatic clustering of notes, but users wanted the whiteboard to stay more in the background. Another system that combined whiteboards and sticky notes was developed by Hilliges et al. (2007). The brainstorming tool supported writing digital sticky notes on an interactive, touch sensitive horizontal surface. At the same time, the sticky notes appeared on a vertical display to allow work at a whiteboard. Each user could work at his own part of the vertical display, but also move a sticky note over to another user. In the *TEAM STORM* system (Hailpern et al., 2007), users could not create sticky notes, but each user could create his own drawing on a tablet PC and then share it with the team at a whiteboard. This way, users could work in parallel at their private work space and add their sketches to a group work space everyone could see. The client applications were implemented in Java and did not require any special hardware.

2.3.2 Remote Collaboration Tools

The first tools to support collaboration at whiteboards for locationally separated teams were *VideoWhiteboard* (Tang and Minneman, 1991a) (based on *VideoDraw* (Tang and Minneman, 1991b)) and *Clearboard* (Ishii and Kobayashi, 1992). They combined synchronous drawing and the ability to observe remote partners at the same time. In the VideoWhiteboard system, a video camera and a video projector were mounted behind a projection screen that served as the whiteboard space. When a user added drawings to the whiteboard, the drawings and a shadow of the user were captured by the camera. Drawings and shadow were then projected to the screen at the remote site. This way, users could see the remote whiteboard marks as well as shadows of the remote collaborators' gestures (Tang and Minneman, 1991a). Facial expressions were not transferred. In the Clearboard system, in which facial expressions were visible, the goal of the authors was to convey the feeling of "talking through and drawing on a transparent glass window" (Ishii and Kobayashi, 1992). In their system, the camera was mounted on top of the project screen, which was angled back at 45 degrees. A half mirror lay on top of the projection screen and the user was drawing directly on the mirror. The camera then captured the drawings as well as the image of the user reflected by a half mirror. At the remote site, the user's image and the drawings were projected onto the partner's screen from the rear. Both systems had the problem that the remote partner's whiteboard marks could not be erased because they were just projected and not really transferred to the other location.

Everitt et al. (2003) also used shadows to mimic the remote person's presence in the *Distributed Designers' Outpost* system. It was based on *The Designers' Outpost* (Klemmer et al., 2001) for co-located web site design (see above), i.e. the paper sticky notes were digitized in the same way. In the Distributed Designers' Outpost images of the paper notes were also transferred to the remote location. If somebody then moved the digital version of a sticky note, inconsistencies with the paper version occurred. However, the system indicated the inconsistency with a red shadow around the changed note. In order to convey deictic gestures, it was possible to draw arrows with a special pen, which were displayed with transient ink on both boards for a few seconds and then faded away. The rear camera that captured the notes' position also detected the peoples' shadows and displayed a blue shadow outline at the remote side. Though the shadows conveyed presence, they were rather bulky and did not show the details of the person's body language.

Another project with a similar approach was *Video Arms* (Tang et al., 2006), which used digital embodiments to enable pointing in a remote setting. A computer vision approach captured the arms of the people, cut them out of the video image, and then reinserted a translucent version on the remote screen as well as on the local device. The main drawback of this solution was that only the arms of the remote persons were visible. Facial expressions and full body gestures were not transferred to the other location. Luff et al. (2011) recently presented the *t-Room*, a room-sized video conferencing system that showed full-scale high resolution video images of remote persons. Eight 65 inch LCD panels were arranged in a circle around a meeting table and conveyed the impression that the remote persons were physically present. Cameras above the meeting tables captured the interactions with documents on the

table. However, there was no possibility to write on a shared surface, and there were no elements synchronized between the locations.

Other than these research projects, there are several web applications enabling people to sketch ideas on whiteboards, e.g. *scribblar*[1], or work with sticky notes, e.g. *Mural.ly*[2], or both, e.g. *RealtimeBoard*[3]. They also allow collaboration with several people. Though these applications look promising, several similar ones (*Dabbleboard*, *skrbl*, *imaginationcubed*) that we have listed before (Gumienny et al., 2011), no longer exist today. In 2012, Google launched Google Drive, which includes *Google Drawings*[4] for real-time collaboration including shapes, arrows, and images. It offers free-form sketching but no sticky notes.

2.3.3 Creativity Support Tools

Besides general digital advantages, tools can also support the individual activities of user-centered design processes beyond the possibilities of analog tools. Especially for the ideation phase, researchers could show that digital tools can help to overcome hindrances of group brainstorming processes (Shih et al., 2009; Streitz et al., 1999). Hindrances that are often quoted (Hymes and Olson, 1992; Shih et al., 2009) are:

- **evaluation apprehension:** people may think that other group members disregard their ideas, leading them not to express all their ideas
- **free riding:** especially in larger groups, people make less effort to think up new ideas, relying on the ideas of the group
- **production blocking:** in verbal group brainstormings people have to wait for their turn to share their ideas. Until then, they may have forgotten their ideas or are not willing to share them after hearing the other ideas.

Hymes and Olson (1992) regard production blocking as the main reason for decreased productivity in groups that brainstorm together at the same time. With the help of their multi-user text editor *ShrEdit*, the researchers could show that parallel input improved the number of generated ideas compared to groups who could only add ideas serially (Hymes and Olson, 1992). In a formative evaluation with three different tools for idea generation, Prante et al. (2002) presented a similar effect. With tools that required turn-taking, the teams produced less ideas than with a tool that allowed synchronous input. Furthermore, there was no clear differentiation between an idea generation and idea structuring phase, but rather a "chaotic pattern of actions" (Prante et al., 2002). Based on their findings, Prante et al. (2002) created a suite of tools that offered mind-mapping functionality (*BeachMap*) and the option to work with "magnetic cards" (*MagNets*) similar to sticky notes. Together with the mobile *PalmBeach* application, users could simultaneously add their ideas on these cards. The *GroupMind* system (Shih et al., 2009) also offered real-time and parallel interactions with mind-maps, i.e. users could jointly contribute their ideas to the same mind map at the same time. In a semi-controlled experiment, the researchers

[1] http://www.scribblar.com, accessed on November 15, 2013
[2] http://mural.ly, accessed on November 15, 2013
[3] http://realtimeboard.com, accessed on November 15, 2013
[4] http://support.google.com/drive/answer/177123?hl=en, accessed on November 15, 2013

could prove that GroupMind performs better than traditional whiteboards for the given tasks.

There are also other ways to enhance idea generation. For example, Wang et al. (2010) proposed the *IdeaExpander*, which provided additional pictorial stimuli based on the teams' conversation. With the tool, people produced more ideas overall and also more "rare" ideas. Furthermore, users appreciated the visual stimuli of the tool (Wang et al., 2010). With the help of *Momentum* (Bao et al., 2010), users were asked to think about the topics of a future group brainstorming beforehand. The system sent out automatically generated prompts related to the brainstorming question in the meeting. The individual responses of the different group members served as a starting point for discussion in the meeting. Users could see which concepts were produced several times and the team had focused discussions more quickly (Bao et al., 2010).

For prototyping and testing, Landay and Myers (1995) introduced *SILK*, which allowed designers to quickly sketch low-fidelity prototypes with an electronic stylus. The sketches could be created in a similar way to paper sketches, but had the digital advantages of easy manipulation and copying sketches. Furthermore, the sketches could be enhanced with interactive behavior and gave more possibilities for testing. There are also products like *balsamiq*[5] or *pidoco*[6], which let users create interactive wireframes with a sketch-style appearance.

With regard to synthesizing or consolidating information from user research, less tools are available. They mainly focus on transferring paper notes to the digital world or augmenting them in order to make use of digital functions (e.g. Judge et al. (2008); Harboe et al. (2012)). Of course, this is beneficial for remote collaboration, but it does not support teams with condensing information and developing a shared understanding of user research data. For a detailed discussion on tool support for information synthesis, see Chapter 6.

2.3.4 Tools for Remote Collaboration in Companies

Global companies that apply design thinking today, such as Procter & Gamble, use a TelePresence video conference system (Cisco, 2010). TelePresence systems convey the feeling of sitting around a table together. However, it is not available to the majority of employees because dedicated TelePresence rooms entail a great deal of expensive equipment. Additionally, there is no common creative workspace for sharing artifacts similar to traditional whiteboards and sticky notes. Remote collaboration tools available to all employees are web conferencing solutions like *Adobe Connect*[7] or *Cisco WebEx*[8]. They offer a simple whiteboard application without sticky notes. From interviews with company employees we learned that people only used the audio and video conferencing capabilities of their web conferencing solution and not the whiteboard.

In order to share artifacts, people in corporate environments mainly use file sharing and desktop sharing systems for their meeting-related content (Shami et al., 2011;

[5]http://balsamiq.com, accessed on November 15, 2013
[6]https://pidoco.com, accessed on November 15, 2013
[7]http://www.adobe.com/products/acrobatconnectpro, accessed on November 15, 2013
[8]http://www.webex.de, accessed on November 15, 2013

Yankelovich et al., 2004). But these systems allow editing for only one user at a time. Others can contribute only via audio or must wait their editing turn. With this "one at a time" mode, distributed and reciprocal synchronous collaboration is not possible. Even though research has proven that real-time and synchronous connectivity is important for successful collaboration (Prante et al., 2002; Shih et al., 2009), standard meetings in large companies still rely on the tools described above. Yankelovich et al. (2004) proposed the *Meeting Central* prototype for improving the effectiveness of distributed meetings. However, the available applications remain similar to the existing tools. For example, the desktop sharing application still only gives one user the ability to "take control".

Other research on collaboration in corporate environments has often focused on social software such as blogs and social networking sites (see Muller et al. (2012) to get an overview of different tools) or social file sharing in an enterprise (Shami et al., 2011). However, Russell et al. (2004) have developed the *Blueboard* for exchanging information at IBM Research. First, it was intended as a public display with quick access to personal information, e.g. the calender (with a badge reader for identification). Afterwards, it supported informal spontaneous small group meetings, too. As it was not really used in this way – probably due to its size, weight and costs (Russell et al., 2004) – the researchers focused on supporting standard meetings as well. In general, the adoption of the Blueboard collaboration software was less successful (Huang et al., 2006). The main difficulties were the proprietary applications on the Blueboard, which made it difficult to add information from personal computers. Overall, the "required effort outweighed the larger screen's benefits" (Huang et al., 2006).

A particularly large problem for the adoption of digital whiteboard systems in companies is the special setup required. Such a setup is not easy to implement in large companies where meeting rooms are always changing (Huang et al., 2006). Additionally, in many meetings, people have a variety of professional backgrounds and no time to learn to use new tools (Espinosa and Pickering, 2006). The participants' lack of time means that even if new tools may benefit users, they do not easily find their way into most companies (Matthews et al., 2011). Tang et al. (2009) also suggest that existing whiteboard systems do not support existing tasks and work practices from the analog world well enough. They propose that large display applications should be flexible enough to support different work methods and allow transitions between the working modes (Tang et al., 2009).

2.4 Guidelines Derived from Related Work

From the findings of related research projects I derived suggestions for a future digital whiteboard system.

- The whiteboard application should remain in the background, rather than providing distractions. Advanced functionality should be available, but not automatically executed (Klemmer et al., 2001)
- Seeing different versions of design ideas is important, thus a history functionality is beneficial to users (Mynatt et al., 1999; Klemmer et al., 2001)

- Easy transitions from whiteboard application to desktop application let users continue working with the developed ideas or structures. If this is not possible, they may prefer desktop applications (Klemmer et al., 2001; Streitz et al., 1994; Huang et al., 2006)
- Each team member should have his own input device. This enables parallel work and circumvents production blocking (Hailpern et al., 2007; Hymes and Olson, 1992; Prante et al., 2002)
- Special hardware should not be a requirement. Digital whiteboard hardware is useful, but the system should be accessible from tabletPCs or desktop computers as well (Hailpern et al., 2007; Streitz et al., 1994)
- Remote whiteboard marks should be erasable as well (Tang and Minneman, 1991a; Ishii and Kobayashi, 1992)
- Eye-contact and seeing deictic gestures are important for awareness and a "natural feeling" in remote collaboration (Ishii and Kobayashi, 1992; Everitt et al., 2003; Tang et al., 2006)
- Large, heavy digital whiteboard hardware may hinder the system's adoption in companies (Russell et al., 2004; Huang et al., 2006)
- Whiteboard applications should support the existing ways of working and not force users to adapt to the system (Tang et al., 2009)

2.5 Summary

Whiteboards and sticky notes are commonly-used tools for user-centered design activities. Over twenty years ago, researchers started to develop digital whiteboard hardware and software. This chapter gave an overview of several systems for co-located and remote collaboration. The systems were developed for different purposes, and most of them only offer either pen-based whiteboard input or sticky notes, not both (see also Table 3.2 for a comparison of systems). Researchers mainly reported on user feedback from colleagues in their own laboratories or pilot user studies. There are no long-term studies of digital whiteboard systems employed for user-centered design work.

The overview of collaboration tools at companies and studies on the adoption of large display applications showed that employees mainly use standard desktop applications when collaborating with remote colleagues. This implies that they cannot apply standard user-centered design activities if their team members are working at other locations. Despite the long history of research studies on digital whiteboard systems and creative collaboration, there is no system that adequately supports remote UCD or DT (Brown, 2009). The question is why. Are the disadvantages of digital tools in this area still too overpowering? Are the benefits they offer too low?

In order to answer these questions and to study the reasons for (non)adoption, we needed a tool that supports the UCD activities described above for co-located and remote teams. Furthermore, it should be based on the findings of the aforementioned research. The next chapter, reveals the concept and architecture of *Tele-Board*.

3. Tele-Board – A Digital Whiteboard Software System

From the previous chapter, we know a number of tools supporting creative and/or remote collaboration already exists. They support different ways of working and different use cases. However, none of these whiteboard and sticky note systems have been used on a large scale. User-centered design activities with the described artifacts (Chapter 2.1.2) can hardly be conducted across different locations.

Therefore, we developed our own system to study which factors hinder the adoption and which factors encourage people to use a digital whiteboard system as part of their work equipment. We started with observations of student design teams at the HPI School of Design Thinking (D-School) in Potsdam, Germany. The D-School teaches a design thinking process with six phases to help students apply DT principles (Lindberg et al., 2010). The activities at the D-School are in line with the UCD and DT activities described in Chapter 2.1.1.

From the observations at the D-School and in conjunction with findings from related work (Chapter 2.4), we derived *working modes* that describe the most important tasks of design thinking teams. From these working modes, we derived requirements for co-located and distributed work support. Based on the identified requirements, we created the *Tele-Board* system, the basis for all studies in this thesis.

In this chapter, Tele-Board's general concept, components and functions relevant for the following studies will be described. The chapter concludes with a juxtaposition of Tele-Board's components with the identified requirements, as well as a comparison with related systems and how they support the requirements.

3.1 Design Thinking Working Modes

In order to anticipate user needs and requirements for a tool meant to support design thinking teams, we needed to understand the way teams work and interact. As Greenberg (2008) states, "groupware design must begin with observations of actual working practices", we observed student DT teams and participated in Dt activities

Figure 3.1: A workspace (left) and a design thinking team at work (right) at the HPI School of Design Thinking.

ourselves. We started this research in 2008 at the HPI D-School in Potsdam and continued the observations over several years with a variety of different teams. Figure 3.1 shows an example workspace and a team working at the D-School. Additionally, in the beginning of 2009, we interviewed several members of a DT team at a company working between Germany and the USA. The interviews especially focused on DT in a company context between different locations.

Through these observations and interviews, we wanted to understand the teams' way of working. Specifically, we wanted to learn more about their communication and collaboration behavior as well as their interaction with different artifacts and tools. We encountered different needs in different situations and summarized them in the form of *working modes*, which are related to the common DT and UCD activities outlined in Chapter 2.1.1. However, the working modes are more detailed and describe specific actions with different working materials.

Handwriting and drawing on a whiteboard Whiteboards are the centerpieces of design thinking activities and informal office work (cf. Chapter 2.1.2). While they are also used for adding sticky notes (see below), they mainly serve as a writing and sketching area. Repeatedly and during all phases of their work, teams write, draw or outline their ideas and concepts on whiteboards. They use whiteboard markers in different colors for adding content and whiteboard erasers or tissue for wiping off content. Sometimes, people purposefully want to use different colors, but the respective pen is empty or not available, so they have to use another color.

Compared to writing or drawing at a table, whiteboards have the advantage that they take up less space in a room, are large enough for all to see the content and work well for focused tasks (Inkpen et al., 2005). In the beginning, people must sometimes adjust to writing on a whiteboard. Oftentimes, just one person is writing at the whiteboard at a time. This work is accompanied by a team discussion (telling the person what to write) and several modifications from team members. As everybody follows the discussion and the creation of content, it is easy to intervene or add comments.

Whiteboard content is often revisited at a later point (for reading or editing) and is therefore carefully photographed if space limitations require the team to wipe off the content.

Creating a personal sticky note Sticky notes are used to jot down facts or ideas in handwritten text, drawings or both. Following the best practices from designers and brainstorming methods, people often use felt-tip pens that can be read from further away and help in keeping with one topic per sticky note due to space limitations. Different colors of sticky notes are used for coding e.g. different interview partners, the author of the note, or different topics.

The creation of sticky notes is done individually and mostly simultaneously by several team members. The majority of sticky notes is either written during storytelling at the *synthesize* activity or during *ideation*.

Adding sticky notes and research material to the whiteboard After a sticky note is created, it is usually added to a whiteboard. However, the time and sequence of adding notes varies. During storytelling, everybody creates several sticky notes and sticks all of them to the board after the session. Oftentimes, all team members do this at the same time. When ideating, people sometimes only add one note to the board and shortly explain their idea, then it is the next person's turn. Other times, one person adds all his ideas at once and then explains their meaning until the next person continues.

In addition to sticky notes, teams also add material from user research to their whiteboards. Most of the time, these are printed photographs from the user's environment, but they could also be timetables, diagrams, posters, or anything else the team collected from interviews and observations.

Rearranging and clustering sticky notes After adding all sticky notes to a whiteboard, people often rearrange the notes according to their semantic similarity. Similar information about a certain aspect is grouped together. Next, people usually define clusters by encircling related groups of sticky notes with a whiteboard marker. They may also add a handwritten caption to each cluster.

Collaborative drawing, discussing, and gesturing During synthesizing activities, like clustering sticky notes, as well as during prototyping, intensive team discussions arise. People need to come to a shared understanding about their research data, the next steps, or the design of their prototype. In order to do so, they often sketch concepts or diagrams on whiteboards to support their ideas. These sketches may be edited (adding or erasing strokes) by different people until the team comes to an agreement. When discussing the sketches, people point to the whiteboards or use other gestures. Through their team members' body language, people can detect if the others agree or not.

Presenting and collecting feedback Especially during prototyping and testing activities, but also at other points, the team needs to present the project's current state to an external audience. Sometimes they show diagrams or clusters on whiteboards, sometimes they present a tangible prototype. The goal is to collect feedback from users, clients, managers, or other stakeholders. The prototype or whiteboard content must therefore be visible to the audience, and the team should hear and see the audience in order to communicate with each other.

3.2 Requirements for a Digital Design Thinking Environment

From these working modes we derived requirements for a design thinking collaboration system. As mentioned, we wanted to support DT teams at one location as well as teams distributed over two or more locations. With reference to the well-established CSCW matrix (Johansen, 1988), the main focus of this thesis lies on the "same time" or synchronous way of working. With regard to the place dimension, there are different requirements for the "same place" (co-located) and "different place" (distributed) categories.

3.2.1 Co-located

A system that supports DT or UCD at one location should offer a large vertical surface that allows pen input and is visible to all team members. In order to support the *handwriting and drawing on a whiteboard* working mode, it needs to offer different pen colors and an eraser for deleting pen strokes. To *create a personal sticky note*, the system must support a separate input area for each team member. This area should allow pen input and be able to change its color. Ideally, it is portable and as lightweight as possible. All team members must be able to add their notes to the shared space any time they like. That is, *adding sticky notes and research material to the whiteboard* must be possible simultaneously. The system should support image import to the shared space. Ideally, it should support other formats, allowing people to add different kinds of research material.

For the *rearranging and clustering sticky notes* working mode, users must be able to move the notes around at the shared space. It should be possible to define clusters of sticky notes and ideally an entire cluster can be moved around. To support *collaborative drawing, discussing, and gesturing*, the shared space should offer simultaneous input and editing of content. It is important that team members can also edit each other's drawings and sticky notes. In order to *present and collect feedback* it should be possible to show the developed ideas or concepts to a larger audience, i.e. on a large screen or surface.

3.2.2 Distributed

A system that supports DT or UCD working modes for distributed locations must first meet the "co-located requirements", then synchronize the actions across all locations. For example, for the *handwriting and drawing on a whiteboard* working mode, the creation and erasing of pen strokes must be transferred to the other locations. It is important this happens in real-time, so that the remote team members can follow the creation of content as if they were standing in the shared space. To support *creating a personal sticky note* and *adding sticky notes and research material to the whiteboard*, it must be possible to create and add these pieces of information from anywhere, not only in the shared space.

Similar to transferring writing and drawing actions, when supporting the *rearranging and clustering sticky notes* working mode, all moving and clustering actions must be synchronized immediately. The remote persons must be able to follow these actions and contribute or intervene. As described before, these actions often go hand in hand

with *collaborative drawing, discussing, and gesturing.* Therefore, simultaneous input and editing of local *and* remote content must be possible. Additionally, the team should be able to hear each other and see the remote person's facial expressions and gestures. Ideally, this "person space" is linked to the shared "task space" in order to have a "reference space" where people can point at sticky notes or drawings and everybody understands what they are talking about (Buxton, 2009). When *presenting and collecting feedback* from an external audience, it is also important to see facial expressions and gestures to interpret the feedback. If this audience is located somewhere else, it must be possible to provide access to the shared team space for external viewers as well.

3.3 The Tele-Board System

Based on the findings of related research projects and our observations of design teams at work, we developed a groupware system for co-located and remote setups, which resembles the usage of traditional whiteboards. Starting with a basic prototype, we constantly revised the system based on user feedback from informal uses and usability studies as well as our own usage over the last years. The general architecture and functional scope presented here were the basis for the studies in the following chapters.

3.3.1 General Architecture and Concept

The Tele-Board system is a digital whiteboard and sticky note software suite that can be used with a variety of different hardware (see Figure 3.2). It allows users to create digital sticky notes on tablets, smartphones, via a web portal, or directly in the whiteboard client. The client software allows users to move the sticky notes, cluster them, and write or draw on the whiteboard surface. All of these actions are propagated to every connected whiteboard client via a collaboration server. Additionally, all actions are stored in a database in order to restore the latest state of the whiteboard content.

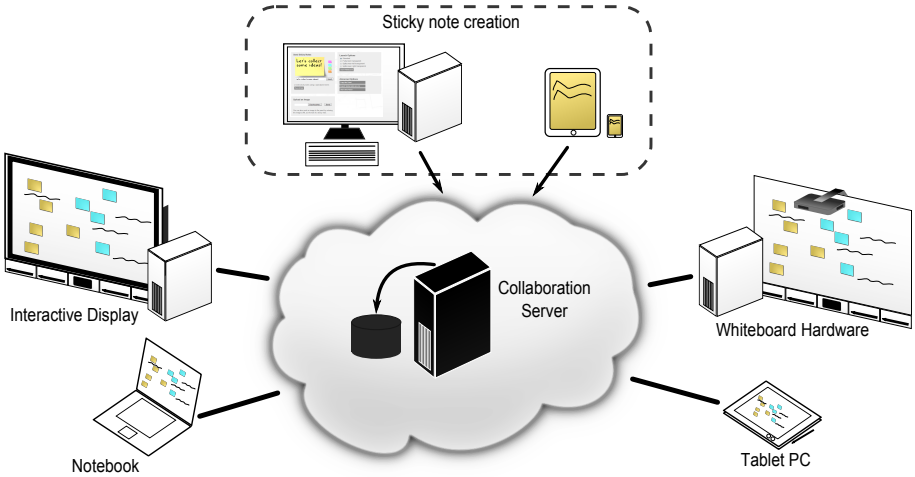

Figure 3.2: The Tele-Board software system. The whiteboard client can be opened on different hardware, for example interactive displays or a standard notebook. Sticky notes can be created via the sticky pad apps or the web portal.

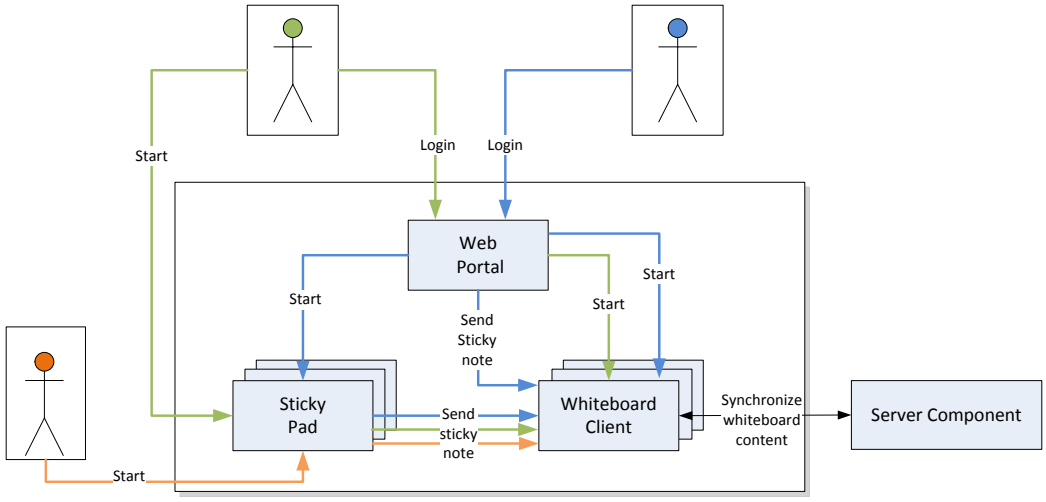

Figure 3.3: Tele-Board's components and how users can interact with them. After logging in at the web portal, users can start the whiteboard client and write sticky note from the web portal or the sticky pad application (blue user). Users can also start the sticky pad iOS or Android apps on mobile devices and send sticky notes to the whiteboard client. Whether the user has started the whiteboard client (green user) or not (orange user) is not relevant.

In an ideal setup, people work with the whiteboard client on interactive whiteboard hardware that allows touch and pen input. This way, interacting with the whiteboard client resembles the traditional way of working with whiteboards. There are different manufacturers of interactive whiteboard hardware and different ways of enabling interactivity (Chapter 3.3.3). For us, it was important that people can use the hardware available to them, rather than having to acquire special equipment. That means Tele-Board also functions on a standard desktop computer or laptop. Certainly, this reduces the "analog whiteboard feeling". See Chapter 3.3.3 for more details on different hardware setups.

For distributed design sessions, it is possible to add a video conference to this setup. In a translucent mode, the whiteboard client can be displayed as an overlay on top of the full screen video of the remote team members. See section 3.3.4 for the video setup options.

3.3.2 Tele-Board's Components

Our goal was to create an interaction model similar to the traditional way of using whiteboards and sticky notes that is easy to access for the users. The Tele-Board system consists of four software components: the *web portal*, the *whiteboard client*, the *sticky pad*, and the *server component*. Users interact with the first three components, see Figure 3.3. The *server component* provides the synchronization and data storage functionality.

3.3.2.1 Web Portal

The entry point to the Tele-Board system is the Tele-Board web portal, accessible through common browsers. After logging in, users can see *projects* and *panels*

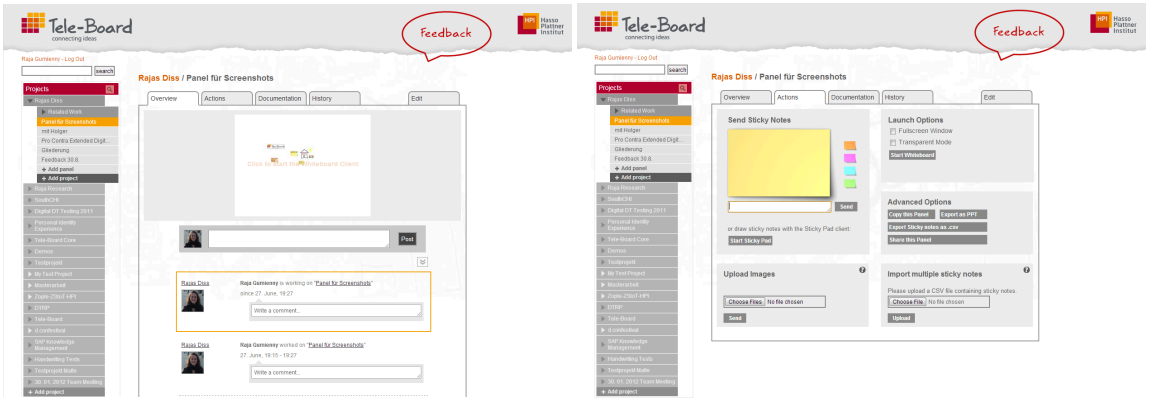

Figure 3.4: The Tele-Board web portal. On the overview tab of a panel (left), users can start the whiteboard client and see the activities of other users. On the actions tab (right), they can write sticky note with the keyboard or use the import and export functions.

they have created or been assigned to. A *project* consists of several *panels* and all those assigned to a project can work on the associated panels. A *panel* is a virtual whiteboard space equivalent to analog whiteboard content.

Different views and functions are distributed over four tabs that allow to interact with the panel. On the *overview tab*, users can start the whiteboard client with the panel's content by clicking on the screenshot of the latest panel state. Additionally, an activity feed shows who has been working on this panel and presents the option to comment on their activities. An orange box indicates that a user is currently working on the content (see Figure 3.4, left).

On the *actions tab* of a panel, several panel specific functions are available (see Figure 3.4, right). The most important one is writing sticky notes and sending them to the whiteboard client. Users can choose the background color for a sticky note, type text in the input field, then send the note to the whiteboard. They can also start the Java-based *sticky pad* client, which has the same functional range as the *sticky pad* apps on tablets and smartphones (see Chapter 3.3.2.3). Furthermore, there are different import and export functions. Users can import images and pages of pdf files from their computers with the help of a standard file upload dialog. They can also import images from the web by pasting the image URL in the sticky note text input field. The whiteboard client will interpret the URL and display the image. It is also possible to "import sticky notes" from a CSV file, i.e. from each line in this text file, one sticky note will be created. In the opposite direction, one can also export all sticky note texts to a CSV file. Additionally, users can export an image of the whole whiteboard content and share the panel with external users, i.e. send them a link to the panel.

On the *documentation tab*, users can find snapshots taken inside the whiteboard client. Additionally, they can upload any kind of file to share with the project members.

The *history tab* especially supports asynchronous work. Starting from the latest state of a panel, users can return to any state of the whiteboard content (see also the *server component* section below) and continue working there in a separate "branch" of this content. They may also download a screenshot of any state or share it via sending a URL to other people.

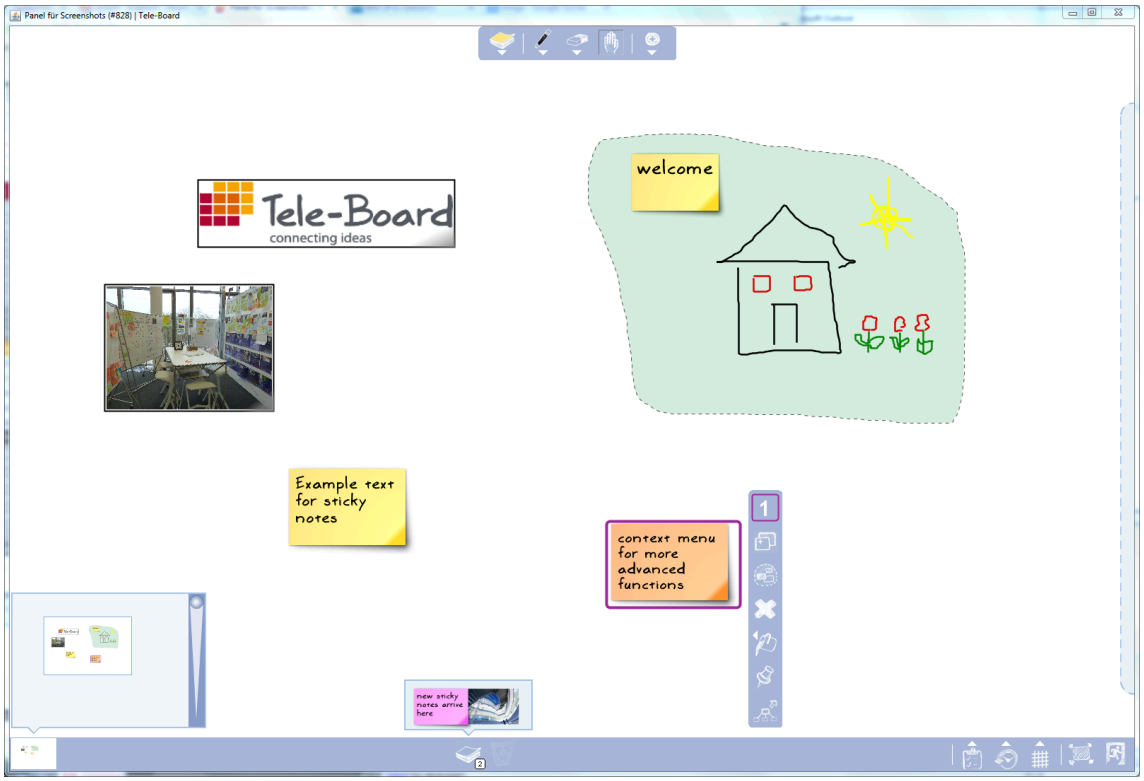

Figure 3.5: The Tele-Board whiteboard client. It offers standard whiteboard application functionality (pen-mode, erase, pan the surface) and more advanced functions like copy sticky notes, change their color, or zoom in and out.

3.3.2.2 Whiteboard Client

The Tele-Board whiteboard client is a Java application as we were looking for a platform-independent solution. With the help of Java Web Start[1] users can start the whiteboard client from their browsers with one click (see Chapter 3.3.2.1). When starting the whiteboard client, the latest state of the respective panel content will be loaded automatically. While the whiteboard client is open, the activity feed shows the person currently "working on" this panel as highlighted within an orange box (Figure 3.4, left).

The whiteboard client's top menu offers core functions, such as the pen mode for writing, the erase mode for deleting pen strokes, and the move mode for moving sticky notes and clusters as well as panning the whiteboard surface (see Figure 3.5). Additionally, there is the voting mode for applying voting dots to sticky notes and a button for creating new sticky notes. All notes can be selected and a context menu offers more advanced functions like copy, cluster, delete, and recolor. A cluster of whiteboard elements can also be created by encircling them. When sticky notes and pen strokes are clustered, it is possible to move around all contained elements together.

Sticky notes and images sent from the web portal or the *sticky pad*, arrive in a dedicated area at the bottom of the whiteboard client. From there, every user can drag them onto the whiteboard surface. The buttons at the right corner of the

[1] http://www.oracle.com/technetwork/java/javase/overview-137531.html, accessed on November 15, 2013

Figure 3.6: The sticky pad apps for iOS (left) and Android (right)

lower menu offer additional functions that are not used very frequently, for example, a timer, a grid function and further adjustments inside the settings menu. The light blue area at the right edge of the whiteboard client serves as a clipboard for transferring sticky notes and clusters to another panel.

The functions are intentionally distributed across different menus according to their relevance to whiteboard use. For standard whiteboard interactions, users only need the top menu functions to switch between different modes and create sticky notes. Further actions related to sticky notes and clusters are available in the respective context menu. Advanced functions are located at the right edge of the bottom menu bar.

3.3.2.3 Sticky Pad

As an equivalent to paper sticky note pads, we created different applications for writing sticky notes. A Java application, which can be started from the *web portal* (see above), is dedicated for tablet PCs or graphics tablets. Furthermore, there is an iOS app for iPads and iPhones and an Android app for tablets and smartphones running on the Android operating system (see Figure 3.6).

All sticky note pad applications provide different pen and background colors, a text input option, and the ability to add images stored on the device or from camera input. After choosing a target panel, sticky notes will be sent to this panel and arrive in the dedicated area at the bottom of the whiteboard client.

3.3.2.4 Server Component

The Server Component connects all parts of the Tele-Board system (see Figure 3.2). It consists of a real-time collaboration server (Openfire[2]), the Tele-Board server plugin and a MySQL database. All events that happen inside the whiteboard client, such as pen strokes, moving a sticky note, or panning the whiteboard surface, are translated to an XML representation and transferred to the collaboration server as Extensible Messaging and Presence Protocol (XMPP)[3] messages, see Figure 3.7. The collaboration server distributes these messages to all other instances of the whiteboard client with the same panel content. When a whiteboard client receives

[2]http://www.igniterealtime.org/projects/openfire, accessed on November 15, 2013
[3]http://xmpp.org/about-xmpp/, accessed on November 15, 2013

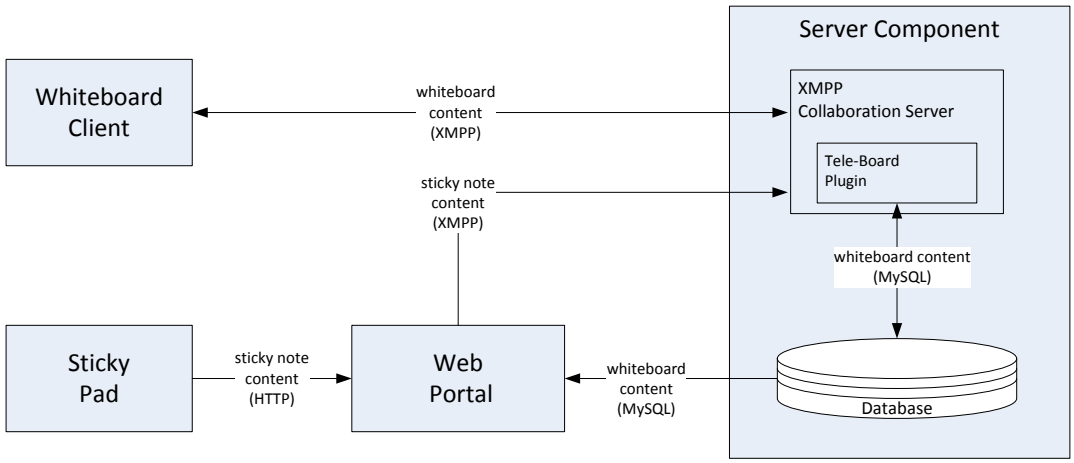

Figure 3.7: Tele-Board's components and their interrelations. Whiteboard and sticky note content is sent to the collaboration server as XMPP messages. The Tele-Board server plugin stores the content in the database and retrieves it to show the latest state in the whiteboard client or history tab of the web portal.

such messages, the UI is updated accordingly. That is to say, new whiteboard elements are created or the existing ones updated at each whiteboard client instance. This way, the whiteboard content stays synchronized, and every user can manipulate all sticky notes and drawings, no matter who created them. By default, all actions are synchronized, but there is the option to stop receiving panning and zooming events from other whiteboard clients. This way, users can work at different areas of the virtual whiteboard without disturbing each other. All pen strokes and sticky notes are still synchronized.

The Tele-Board plugin at the collaboration server stores all events from the synchronization messages in a database. When a user starts the whiteboard client, the latest state of the respective panel is restored from the database (see Figure 3.7). When users send new sticky notes with the *Sticky Note Pad* or via the web portal, they are stored with a "queue" flag and displayed at the bottom of the whiteboard client when opened. That is to say, users can create sticky notes without opening the whiteboard client and add them later or even let other users add the notes to the board.

The content of the *history tab* in the web portal (Chapter 3.3.2.1) is also based on the events at the server's database. When a user requests a screenshot of a particular point in time, an image of this panel state is created from the respective events. For more details on the synchronization of whiteboard events and the creation of history screenshots, see Gericke et al. (2010).

3.3.3 Hardware Independence

In order to create a working environment that resembles the analog way of working as closely as possible, the Tele-Board system was intended for digital whiteboard hardware. However, we did not want to develop specialized hardware for our laboratory only. It was our goal to allow as many users as possible use our system at their current working environment.

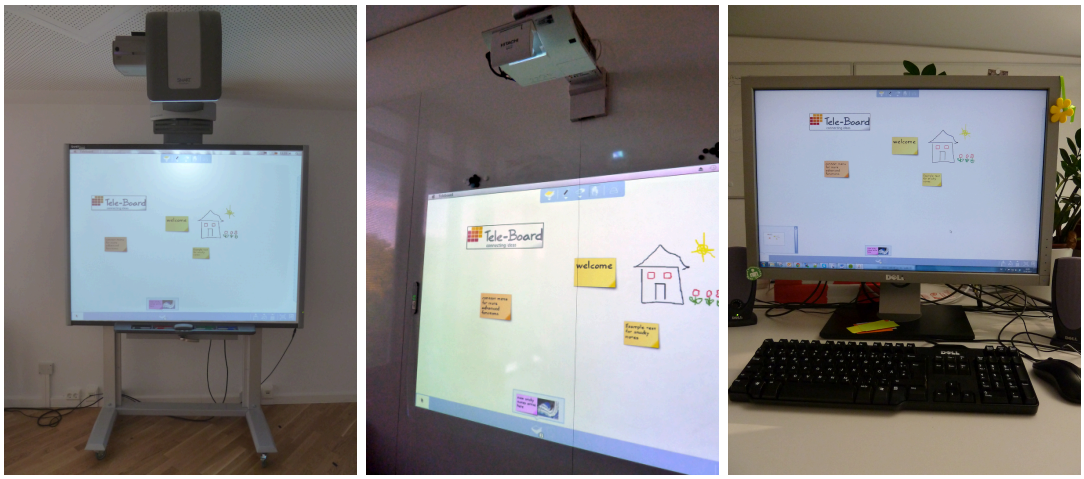

Figure 3.8: Tele-Board in use on different hardware: at digital whiteboard hardware, e.g. from SMARTtech (left), at a lightweight interactive surface, i.e. a projector plus Luidia eBeam (middle), and at a desktop computer (right).

In contrast to related research projects started twenty years ago, a variety of hardware from different manufacturers is currently available. While they offer different display and input capabilities, all have in common that they have to be connected to a computer and basically work as very large displays. A natural user experience requires multiple touch input with fingers and pens. Although the development of interactive whiteboard hardware has advanced during the last years, off-the-shelf multitouch devices in the size of an analog whiteboard (i.e. at least 70 inches) are still expensive and not commonly available. There are different technologies for enabling touch input (Maxwell, 2007), each of them with different advantages and disadvantages. The market leader of interactive whiteboard hardware, SMART Technologies Inc.[4], offers two categories of whiteboard hardware: projector-based interactive whiteboards (see Figure 3.8, left) and interactive displays. SMART Technologies also offers a software development kit (SDK), which we integrated in our whiteboard client to gain a higher sampling rate and accuracy. This more precise pen input enables a more natural feeling of writing on the whiteboard. Additionally, the input devices are mapped to the whiteboard client functions, e.g. when a user takes the red pen, the software switches to the red pen mode, when he touches with the finger, the move mode is enabled. The disadvantages of this specialized whiteboard hardware are its large size and weight, resulting in limited mobility. Furthermore, acquisition costs are quite high.

There are also less expensive and more portable interactive whiteboard systems, such as Luidia eBeam[5]. The main components are an infrared receiver and its associated pen. Together with a standard projector, this setup enables pen-input for any application. Ideally, a short-range projector is mounted on top of the projected area, as in Figure 3.8, middle. This way, users do not cast their own shadows on the whiteboard surface. Compared to the interactive whiteboard hardware described above, the input is less precise and finger touch is not possible. However, it can be easily moved to other locations and still offers a whiteboard-like feeling.

[4]http://www.prweb.com/releases/interactive_whiteboard/IWB_electronic_whiteboard/prweb9733058.htm, accessed on November 15, 2013

[5]http://www.e-beam.com/, accessed on November 15, 2013

If users do not have any specialized hardware, they can still use Tele-Board. In this case, they would start the whiteboard client on a standard desktop computer or laptop and use the mouse or touchpad as the input device (see Figure 3.8, right). Of course, drawing or scribbling text with a mouse is cumbersome and the whole setup is quite different from analog whiteboard use. However, people working from home or other places outside the office or team rooms may still contribute to a whiteboard session.

Not only can the Tele-Board whiteboard client be used with different kind of hardware, but the digital sticky note pad can also be used on different smartphones and tablets, see Chapter 3.3.2.3. Additionally, users can add their ideas with a keyboard via the web portal.

3.3.4 Video Setup Options

Digital whiteboard hardware enables interaction with the Tele-Board system in a similar way as in the analog world. The synchronization of whiteboard events lets users see the same whiteboard content even in front of whiteboards at different locations. To improve the feeling of working together as if in one room, a video between locations should be included. We suggest two different setups: the sophisticated overlay setup or the more convenient side-by-side setup.

Figure 3.9: Tele-Board's remote location setups. Left, the transparent whiteboard client is on top of a video conference in fullscreen. In the side-by-side setup (right), the video conference is on an extra display orthogonal to the Tele-Board whiteboard client.

Overlay setup As described in the requirements section for distributed work, a shared reference space between the person and the task space is desirable (Buxton, 2009). In order to achieve this, we start a video conference of the remote location in fullscreen on the whiteboard display. We then layer the Tele-Board whiteboard client window with a semi-transparent background (background color white with an alpha value of 0.5) over the video conference, see Figure 3.9, left. In this setup, the camera for the video conference has to be at a certain position in front of the whiteboard. Basically, the whiteboard content must perfectly fit the camera detail. Finding this position requires some calibration. However, when this position is found, people can use deictic gestures on whiteboard elements in their discussions.

Side-by-side setup To overcome the calibration efforts, we suggest another setup. Similar to Tanner and Shah (2010), we position an extra display and the webcam for

the videoconference next to the person in front of the whiteboard. When the person is looking at the whiteboard, his remote collaborator can see his profile. However, we do not position the camera in an 90 degree angle towards the whiteboard, but more in a 70-80 degree angle. This way part of the whiteboard is still visible, and it is possible to see who is manipulating the whiteboard content, see Figure 3.9, right. Additionally, it is easier to turn to the remote person and see their facial expression. Though the reference space is rather limited in this setup, the setup efforts are greatly simplified.

In an optimal setup, both video channels can be used. One video is in the background of the whiteboard client for shared reference space to convey deictic gestures. The other video for seeing facial expressions is displayed on an extra screen.

3.4 Overview: Relationship Between Design Thinking Working Modes, Requirements, and Tele-Board's functions

To show how Tele-Board responds to the design thinking working modes we identified and the requirements we derived, Table 3.1 lays out their relationship. For each working mode, the respective co-located and distributed requirements are listed. Depending on the working mode, different components and their functions are relevant for the user. Tele-Board's server component synchronizes the respective interactions and thus facilitates the requirements for distributed setups.

3.4.1 Comparison with Other Tools

The former section has shown the relationship between Tele-Board's functions and the requirements for co-located and remote design thinking work. In the following, I will discuss how related research projects and systems addressed the identified requirements, focusing on the most cited and well-known projects and systems in Chapter 2.3.

The systems developed for co-located design work, *Tivoli, Flatland, i-LAND, and Creative Problem Solving*, supported handwritten input and editing. Of these systems, only the i-LAND environment (Streitz et al., 1999) and the Creative Problem Solving system (Hilliges et al., 2007) enabled each participant to create personal input and move or structure notes at the whiteboard. All systems were created for co-located setups and therefore do not meet the requirements for distributed work.

The systems created for distributed whiteboard work, *VideoWhiteboard, Clearboard, and Distributed Designers' Outpost*, enabled handwritten input and let users see their remote colleagues' drawings. However, only in the Distributed Designer's Outpost system (Everitt et al., 2003) could users edit the remote whiteboard elements – at least the digital ones. Furthermore, only this system gave the possibility to create personal input and move or structure notes at the whiteboard. Only Clearboard (Ishii and Kobayashi, 1992) let users see gestures and facial expressions. Of all related work systems, Clearboard was the only one that provided a reference space, i.e. a connection between the video and the workspace.

Table 3.1: Relationship between design thinking working modes, requirements for a digital design thinking environment, and Tele-Board's components and functions

Design thinking working modes	**Requirements for a digital design thinking environment**		**Tele-Board's components and functions**
Handwriting and drawing on a whiteboard	co-located	Support drawings and handwritten input	Whiteboard client • Pen mode • Erase mode
	distributed	Synchronize whiteboard strokes; see writing / drawing	
Creating a personal sticky note	co-located	Support own/ hidden/ personal input for each participant	• Sticky pad apps • Web portal actions tab
	distributed	Create notes anywhere	
Adding sticky notes and research material to the whiteboard	co-located	Support adding sticky notes, external media, images	Image upload and import from • Web portal • Sticky pad apps
	distributed	Add notes and images from anywhere	
Rearranging and clustering sticky notes	co-located	Support for moving / structuring notes	Whiteboard client • Move mode • Zoom & overview • Recoloring & copy function • Cut & paste • Grid layout
	distributed	Synchronize moving, clustering; simultaneous input and editing of local and remote whiteboard elements	
Collaborative drawing, discussing, and gesturing	co-located	Simultaneous input and editing	• Whiteboard client • Sticky pad apps and actions tab • Video overlay and side-by-side setup
	distributed	Synchronize whiteboard content; see gestures and facial expressions; reference space (connection between video and workspace)	
Presenting and collecting feedback	co-located	Show design work to large audience	Web portal • Export link to panel • Export screenshots • Access rights administration
	distributed	Provide access to external people; open anywhere (if audience at other location)	

Among the commercial products available for remote collaboration *TelePresence, web conferencing, and Google Drawings*, TelePresence systems only meet the requirement of seeing gestures and facial expressions. In TelePresence, there is no shared whiteboard application for collaboration. Web conferencing and Google Drawings offer a whiteboard application which supports free-form drawings, synchronization of whiteboard elements and concurrent editing. However, they do not enable the creation of personal input or the moving or structuring of sticky notes.

For an overview of how the different systems meet the requirements for a digital design thinking environment, see Table 3.2.

3.5 Summary

In this chapter, I presented Tele-Board's concept and architecture. The Tele-Board application consists of four components – web portal, whiteboard client, sticky pad,

Table 3.2: Comparison of existing systems and their relevance for the working mode requirements.

	Co-located					**Distributed**					
	Drawings & handwritten input	Create personal input	Add external media and images	Moving / structuring of notes	Present design work to audience	Synchronize white-board interactions	Add notes & images from anywhere	Simultaneous input & editing of local & remote content	See gestural and facial expressions	Reference space	Access for external people
Tivoli	✓		✓		✓						
Flatland	✓				✓						
i-LAND	✓	✓	✓	✓	✓						
Creative Problem Solving	✓	✓		✓	✓						
Video Whiteboard	✓				✓	✓					
Clearboard	✓					✓			✓	✓	
Distributed Designers' Outpost	✓	✓	✓	✓	✓	✓	✓	(✓)			✓
Google Drawings	✓		✓		✓	✓		✓			✓
Web conferencing	✓		✓		✓	✓		✓	✓		✓
TelePresence									✓		
Tele-Board	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

and server component. They allow users to conduct co-located whiteboard interactions such as free-form input, creating personal content on virtual sticky notes, and clustering sticky notes. For remote collaboration, all whiteboard interactions are synchronized and users can create content from anywhere.

The software application can be used with different hardware setups, depending on the respective situation and user needs. In a co-located design thinking project space, sophisticated digital whiteboard hardware with pen input as well as tablets or smartphones should be used. In a remote setup, the video overlay plus an extra display for facial expressions improve the collaboration experience. Additionally, other remote participants may contribute from their laptops.

To evaluate if Tele-Board really supports the design thinking working modes and which role the hardware actually plays, we studied Tele-Board in two different setups: a co-located design thinking challenge with different kinds of hardware equipment (laboratory study), and a large company across different locations mainly at desktop computers (field study).

4. Acceptance of Digital Tools for User-Centered Design

The former chapter introduced Tele-Board as a software that supports user-centered design or design thinking workflows. It is based on working modes we observed in analog environments, as well as interviews with people working in distributed settings. A variety of digital tools to support creative work with whiteboards already exists (cf. Chapter 2.3.1), but analog tools are still preferred, especially by designers (Landay and Myers, 1995; Klemmer et al., 2008). What are the main reasons for this preference? What are the obstacles to adopting digital tools? Can we transfer working with paper sticky notes and traditional whiteboards to the digital world?

To answer these questions, we wanted to test how well Tele-Board supports design thinking in a co-located setup. Without any additional obstacles, like audio and video connections, we wanted to find out if Tele-Board's interaction design was suitable for design thinking projects. Although we tried to stay as close to the analog metaphors as possible, a digital system certainly has a different look and feel than analog tools. Additionally, the different hardware setups we described also influence the experience with the Tele-Board software.

This chapter presents a qualitative study on the use of Tele-Board for a one-day design thinking challenge. All participants in this study were accustomed to working with analog tools and it was our goal to find out how well they could use the digital tools for their usual way of working. Furthermore, we wanted to test the Tele-Board software with a focus on concept and usability. We were also eager to know which whiteboard and sticky note hardware is most suitable for this way of working.

Results show that all participants could well accomplish their usual way of working with the digital environment and came to satisfying results. However, the acceptance and readiness to use a digital system varied among participants. Some users said they would be happy to use it for other design thinking activities, others preferred working with analog tools and "getting away from the computer".

We also found that the digital whiteboard hardware to some extent hindered a smooth integration into the teams' workflow. On the other hand, iPads generally worked as a good substitute for paper sticky note pads.

4.1 One-Day Challenge with Tele-Board

User-centered design or design thinking comprises different activities that a team usually conducts (cf. Chapter 2.1.1) and in many cases, whiteboards and paper sticky notes are the main working material (cf. Chapter 2.1.2). At the HPI School of Design Thinking, students get acquainted with the different activities and how to use the working material through "learning by doing". They start with "one-day challenges" where they do all activities from *Analyzing the problem and user needs* to *Prototyping and Testing* in one day. They continue with with one-week, three-week, and six-week projects. After this time, the students can apply different design methods and are used to working with whiteboards, sticky notes, and prototyping material.

In order to evaluate if Tele-Board really supports UCD / DT activities (i.e. the working modes we identified in Chapter 3.1), we asked students with DT experience to work with Tele-Board on a one-day challenge. Because they were very used to the "analog world", they could give us insights into how well Tele-Board supports their usual way of working and which obstacles it still has.

4.1.1 Research Questions

In general, we wanted to know how well Tele-Board supports the DT working modes. Specifically, we had the following research questions for this study:

- Are the teams able to complete a whole design challenge during the given time frame, and do they come to satisfying results?
- Does Tele-Board support all design thinking activities?
- Does Tele-Board have an influence on the team dynamics? Does the digital environment exclude any team members?
- Is a short introduction sufficient to get used to the system? How long does it take until the teams can use the system without problems?
- How is the overall usability of the Tele-Board functions?
- Which digital whiteboard hardware do the users prefer?
- Which sticky note hardware devices do the users prefer?
- Is Tele-Board advanced enough for design thinking projects?

4.2 Method and Setup

We conducted a qualitative case study with five teams. Each team was working on the same design challenge, namely: "How might we enable a design thinking team to conveniently document their project in a way that fits the needs of all different parties involved?" Similar to other challenges the students had worked on, this challenge was intentionally open-ended and the outcome was not specified.

4.2.1 Participants

The study was conducted in five teams with four participants each. Except for one team, all consisted of two female and two male participants (in total: eleven female and nine male participants). Their age ranged between 24 and 32 years (28 on average). As we wanted to make sure that the participants had similar prior experiences with analog tools, all of them were alumni of the D-School in Potsdam. Most people knew each other from before, but none had worked earlier in the same team constellation as in this study.

4.2.2 Procedure

In the beginning of the study, we demonstrated the use of Tele-Board for remote setups as this was communicated as the purpose of our general research before. We wanted to make sure all participants had the same prior knowledge about the project. Afterwards, we told them that they were to use Tele-Board in a one-location setup and evaluate its use for design thinking work. Next, we showed them all the relevant functions of the whiteboard client, the web portal, and the digital sticky note pads. The participants had time to try out all functions and to get used to the digital whiteboards and sticky note devices. The whole introduction lasted about half an hour for each team.

In order to shorten the overall time for the study and to have comparable input for all teams, we substituted the user research phase with videos of interviews with different stakeholders on the documentation process (project partners and staff members of the D-School for internal and external communications). In pairs, the participants watched the videos, each about ten minutes long and with different content. This way, every two participants got different information that they had to tell their colleagues about. While watching the videos, participants could take notes on paper or with the digital sticky note pads.

The rest of the study, i.e. all other activities of the design challenge were done together as a team of four. The teams completed all activities as they had learned during their design thinking education: storytelling, synthesis, ideation, prototyping and testing. In the end, they had to present their final prototypes for the Tele-Board team and staff members of the D-School. In total, they worked at the design thinking challenge for five hours, including a lunch break.

After the study, all participants filled in a questionnaire, then talked about their experiences in a group interview.

4.2.3 Technical Setup

Because we wanted to know which digital whiteboard hardware works best for design thinking working modes, we provided two different types of whiteboard hardware: a SMART Board 680i2 interactive whiteboard system (Figure 4.1, left board) and a SMART Interactive Display 6052iB (Figure 4.1, right board). The SMART Board projects the content onto a foil-like surface that detects interactions through pressure (resistive technology). The SMART Display is an LCD display combined with cameras for detecting pen and finger input (DViT technology). Both of them only allowed single touch. Though newer versions of both devices allow dual-touch, they were not available at the time of our study.

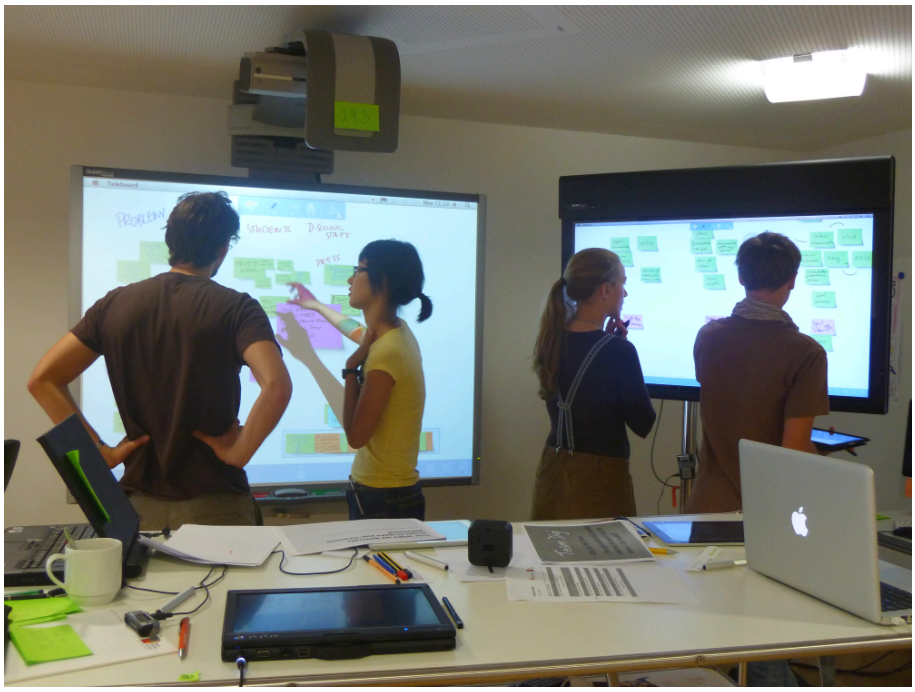

Figure 4.1: Working environment for the one-day design thinking challenge. We provided two kinds of digital whiteboard hardware and different devices for creating sticky notes. The table and chairs were the same in the analog environment.

For writing sticky notes, the participants could use these devices: four iPads with the sticky pad app (including special iPad pens), a TabletPC (Dell Latitude XT2), a digital pen (Pegasus Mobile NoteTaker) and a laptop for writing sticky notes via the Tele-Board web portal (see Figure 3.4). The digital pen could only be used together with a receiver connected to a laptop. It looked like a standard ballpoint pen and users could write on a standard paper sticky note. When a user pressed a button at the receiver, all strokes written on the paper note were transferred to the Tele-Board system, and a new digital sticky note with the same content as the paper version appeared in the whiteboard client.

4.2.4 Measures

In order to examine the participants' way of working and to find out how well they could accomplish the design task, we observed the teams during their work and took notes on our observations. Additionally, we took audio and video recordings to examine specific situations.

After completing the design task, each participant filled in a questionnaire with Likert-scale and free-form text questions. The questions covered different research questions with regard to team dynamics, usability, and hardware equipment, among others (see Appendix A for the full questionnaire). Afterwards, we conducted a focus-group interview with the whole team. We asked about their general experience and areas for improvement. All participants spoke eagerly about their experiences – both positive and negative.

In addition to the observations, questionnaire, and interviews, we had 13 experienced design thinkers (coaches and D-School staff members) evaluate the final prototypes

with regard to their usefulness (adapted from von Thienen et al. (2011), see Appendix A). We also examined the usage statistics in order to find out which devices were used how frequently and which users participated how much.

4.3 Results

The findings from the different evaluation metrics are grouped thematically, based on the research questions in Chapter 4.1.1.

4.3.1 General Comparison: Analog vs. Digital

Overall, all five teams completed all activities of the design thinking process and presented a prototype within the given time frame. There were no major differences in the timing of the different activities between the teams and regarding a one-day challenge with traditional tools at the D-School.

From observations and interviews we learned that, in general, the team's usual way of working did not have to be changed. Some participants said that there was hardly any noticeable difference between traditional tools and the digital system. They even claimed it to be time-saving compared to the analog ones. In the general feedback box at the end of the post-test questionnaire, people wrote:

> Within the Design Thinking process there was no real difference between using digital or analog boards. Great work :D love it.
>
> I was stunned how good it really worked out!! Thank you for the fun day.
>
> I love the concept of bringing the whole thing to the digital world. The size of the projector whiteboard is perfect. Some detailed interaction paradigms can still be improved to humanize it more.

On the other hand, some participants had difficulties getting used to the system and said it would slow down their work. This was mainly noticeable among those who were rather cautious about trying out all functions (see the usability and learnability section below).

The users perceived and evaluated their overall satisfaction in using a digital environment differently. In interviews after the study, some participants stated that Tele-Board worked well for a digital tool, but if they had the choice, they would rather work with pen and paper than be in front of a computer or monitor. In contrast, others said, that they had to digitize the content anyway at some point, and if it was digital from the beginning, this could be omitted. The preference was related to an overall preference to using digital tools. Users who liked the digital environment stated that they generally preferred digital tools over their analog counterparts. For all users, we see the results are rather balanced and there is no clear tendency towards traditional or digital tools, see Figure 4.2 (left mean: 2.8, SD: 1.11; right mean: 3.1, SD: 1.17).

In the post-task questionnaire, we asked users what they thought were the major advantages and major disadvantages of traditional tools and Tele-Board (four free form answer fields, see Appendix A).

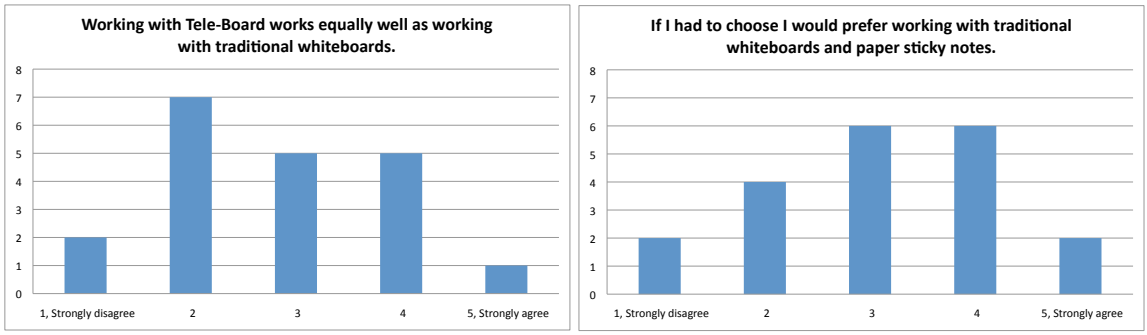

Figure 4.2: Comparison of Tele-Board with traditional whiteboards and paper sticky notes. Answers from Likert-scale questions in the post-test questionnaire, n=20.

Advantages

From the participants' point of view, the major advantages of traditional (analog) whiteboards were: the ability to work with several people at the same time, the tangibility or haptic feeling, and the speed, i.e. quick manipulation. Other things mentioned were: the ease of use because everyone immediately understands it, the low cost and no need for special equipment. Further advantages of normal whiteboards were related to the digital whiteboard hardware, e.g. difficulties drawing on them and the poor resolution of the boards.

As the main advantages of Tele-Board (digital), the participants mentioned: automatic saving and documentation, several special functions such as clustering, changing colors of sticky notes, zooming, and no waste of paper. Additionally, they stated the opportunity for remote collaboration and chance to write sticky notes with mobile devices from any location.

Disadvantages

Participants thought the main disadvantages of traditional (analog) whiteboards were the waste of paper and sticky notes that fall down after a while. Furthermore, they mentioned difficulties with documentation and the limited number of available boards: the only way to win new space on a board was taking pictures of the used boards, then wiping off their content. This eliminates future editing possibilities. They also mentioned that the boards required a lot of space and had limited mobility.

The greatest disadvantage of Tele-Board (digital) was seen as the single touch capabilities of the whiteboard hardware, meaning only one person at a time could work at the whiteboard. Another problem was the input delay of the digital boards, especially when writing on the whiteboard surface. Thereby people described the system as too "slow" or said, "If it was a little bit faster and more than one person could work on the same board, then it would be really fun."

Participants also considered the digital equipment quite expensive, and some functions did not work intuitively enough or had bugs. See also the following section on usability and complexity of functions.

Expert Evaluation of Prototypes

In order to evaluate whether the teams came to satisfying results, we invited 13 design thinking coaches and let them watch videos of the prototype presentation from

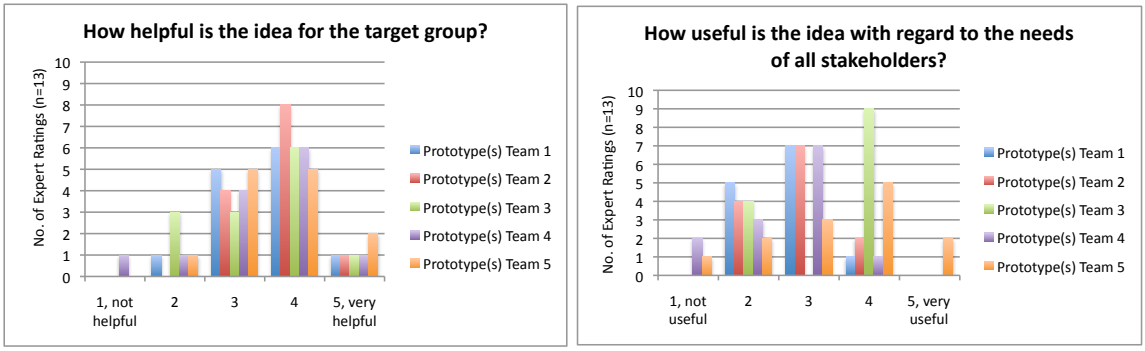

Figure 4.3: Expert evaluation of the prototypes the teams created. Adapted from von Thienen et al. (2011).

each team. The videos were shown in random order, and each was approximately 5 minutes long. The coaches then had to rate the prototypes with regard to the helpfulness for the target group (that the teams had focussed on) and the usefulness for all stakeholders in the documentation process. As the challenge was design thinking related, all coaches could assess whether the prototype was useful or not. All five teams independently chose design thinking students as their target group after synthesizing their data.

The results of the evaluation shows that the prototypes of all teams were considered quite helpful for the target group, see Figure 4.3, left (mean values for each team ranked between 3.38 and 3.77 (SD between 0.6 and 1.04) with 1 = Not helpful and 5 = Very helpful). With regard to the usefulness for all stakeholders, the results are lower, see Figure 4.3, right. However, the mean values for each team range between 2.54 and 3.38 (SD between 0.63 and 1.19) with 1 = Not useful and 5 = Very useful. So all teams created prototypes that were rated with medium high scores for usefulness.

4.3.2 Support for Different Design Thinking Activities

As the study encompassed several hours with different activities of a design thinking project, we were interested if all ways of working were supported equally well. Therefore, we asked the participants which activities Tele-Board supported and which activities it did not.

They rated the Tele-Board especially well for brainstorming, followed by presenting content, and the synthesis of information, i.e. clustering and sorting ideas (see Figure 4.4 for the ideation result of one team). Participants liked the clustering functions of Tele-Board because it was possible to move clusters around, and they had a better overview than on traditional boards. When presenting, they could easily hide and show information with the help of the zoom and panning functions. Additionally, they mentioned that it was helpful to recolor sticky notes. This way, the color could first be related to a person and afterwards to a specific topic. With regard to sustainability, they liked easily integrating pictures from the internet or a camera without printing them. In general, they also liked storing everything automatically and the ability to go back and forth within the history of the whiteboard content if needed.

When we asked which activities Tele-Board did not carry out well, they mainly mentioned working together at the whiteboard and drawing or writing on the whiteboard

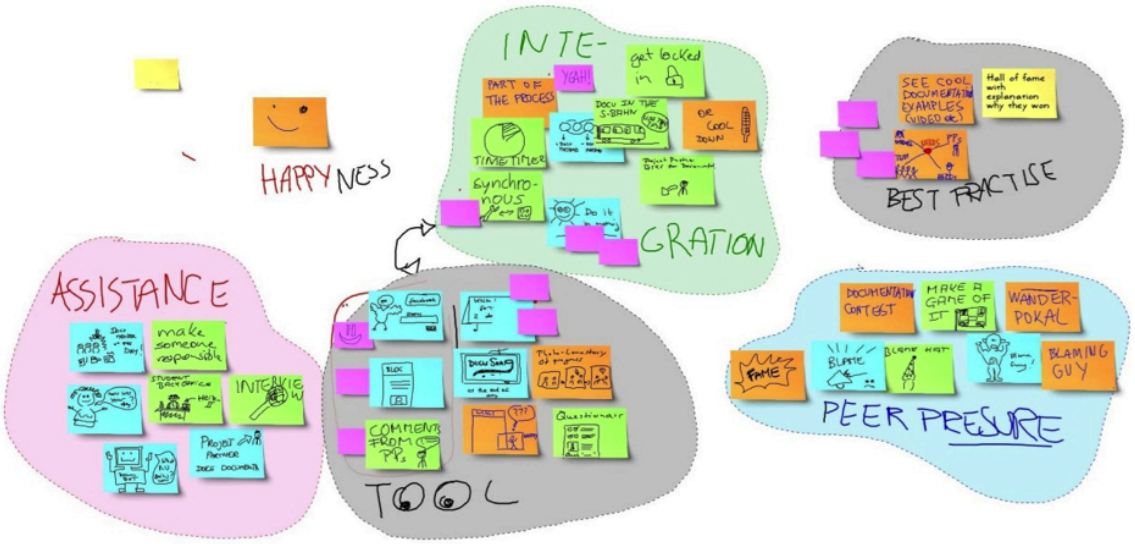

Figure 4.4: Screenshot of the Tele-Board whiteboard client after ideation. Participants especially appreciated the possibility to create clusters and move them around.

surface. Both issues were related to the digital whiteboard hardware; see also the hardware equipment section below. With regard to the software, i.e. Tele-Board's functions, most participants missed an "undo" option. When we started with the design of Tele-Board, we intended to stay with physical metaphors (Mynatt et al., 1999; Terrenghi et al., 2007) as closely as possible. Therefore, we focussed on functions that were possible with traditional whiteboards and added some features that had additional value, such as recoloring and moving clusters. We tried to avoid desktop-like interactions, such as "undo" or copying sticky notes in order to keep the interface simple and to keep the whiteboard look-and-feel. Though users stated how realistic the digital whiteboard interaction felt, they were still expecting all standard functions they knew from desktop applications.

4.3.3 Influence on Team Dynamics

Most participants perceived the teamwork as productive and collaborative among team members, see Figure 4.5 (left mean: 4.2, SD: 0.62; right mean: 4.35, SD: 0.99).

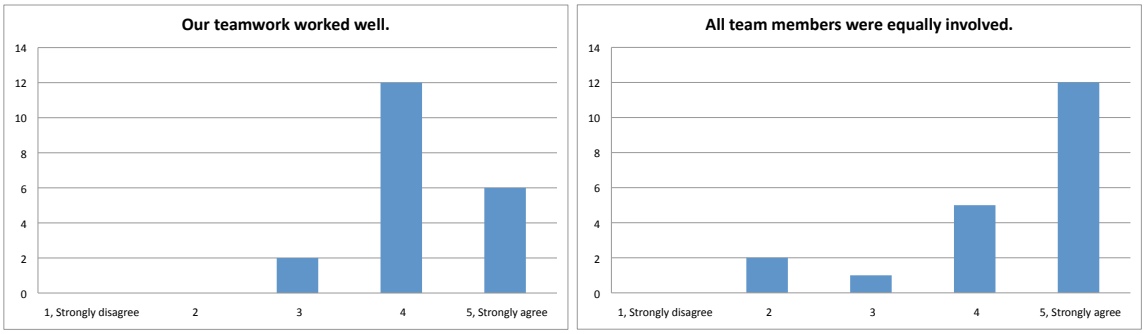

Figure 4.5: Post-test questionnaire data on team dynamics. Most users considered their teamwork quite positively and had the feeling that all team members were equally involved.

From the usage statistics, we could see that the number of sticky notes that each participant created with his own iPad varied, see Table 4.1. On average, each participant created 38.05 sticky notes (SD 18.86). The average number of sticky notes

per team member ranged between 24 and 55 notes. In two teams, one person created 20-30 sticky notes more than the other team members. In two other teams, two people created twice as many sticky notes as their team members. However, in two teams, several sticky notes were written with the laptop, making them not allocable to one user. From observations, we could not tell that writing more or less sticky notes had an influence on the team dynamics. Instead of writing sticky notes, some participants interacted more with the whiteboards or stated their ideas verbally whilst others wrote them down.

Table 4.1: Number of sticky notes created with the iPad per user. There are quite big differences between the different users, but we could not observe that the differences had an influence on team dynamics.

	User 1	**User 2**	**User 3**	**User 4**	**Mean per user**	**SD**
Team 1	40	23	82	75	55.0	28.15
Team 2	58	28	32	20	34.5	16.44
Team 3	37	58	44	34	43.3	10.69
Team 4	52	32	24	26	33.5	12.79
Team 5	36	9	35	16	24.0	13.59

As mentioned above, when we asked for the disadvantages of the digital environment, several users cited the missing multi-touch capability of the whiteboards. This way, only one person could work at one board and this changed the team dynamics.

> Team members can't work at the same time. –> one operator.
>
> Working simultaneously with many people at the same board –> difficult for teams.
>
> Only 1 person can work at the screen (Could also be an advantage :))

Therefore, we think it was very important that every team member had their own sticky note device for quickly jotting down their ideas and thoughts. This way, it was possible to circumvent the missing multi-touch capabilities of the whiteboard hardware to some degree. While one person was operating the whiteboard, the others could still contribute their ideas and discuss the topic as a team.

4.3.4 Usability and Learnability of Tele-Board's Functions

We observed that the ease of use and comfort with the system was related to general openness and curiosity towards new technologies and digital tools. That is to say, participants who tried out all Tele-Board functions enthusiastically in the beginning also learned the functions much faster. Not surprisingly, participants who had used an iPad before had less problems using it, compared to others who had never held one in their hands.

On the other hand, some participants had difficulties getting used to the system and said it would slow down their work. This was mainly observable with people who were rather cautious trying out all functions. When they could not find what they

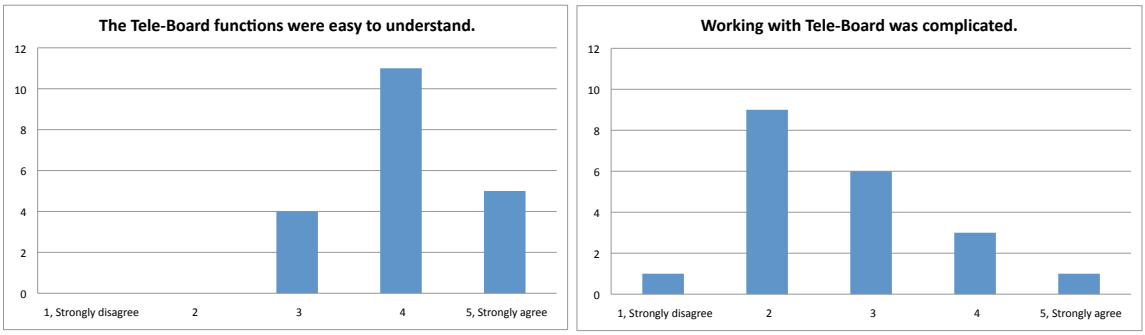

Figure 4.6: Likert-Scale responses to the ease of use of Tele-Board's functions and how complicated it was to work with the system.

were looking for in the first place or the system did something they did not expect, they did not try out other things afterwards.

Still, all participants learned how to use the functions they needed after no more than an hour. We also observed that it was a great advantage when at least two of the four team members were eager to become acquainted with the system, because they then showed the others what they found out. After a short while, the whole team had no difficulties anymore. In teams where all participants were rather cautious, it took them longer to get used to the Tele-Board system.

In order to evaluate the usability and general user experience of Tele-Board, we also asked the participants to give their ratings on Likert-Scales questions. Though there were participants who considered working with Tele-Board complicated, many people did not. The majority also thought that Tele-Board's functions were easy to understand, see Figure 4.6, (left mean: 4.05, SD: 0.69; right mean: 2.7, SD: 0.98).

This is also reflected in some of the comments in the post-test questionnaire:

> It is nice that the use of paper is reduced by the Tele-Board. It is fun to work with it and it's easy too.
>
> I liked the whole experience, nice atmosphere and I liked our idea and working in total with Tele-Board. I hadn't expected that learning to work with it would be so easy and quick to learn, but the drawing experience is horrible!! Must be improved.

4.3.5 Advantages and Disadvantages of Hardware

In addition to the interaction design of the system, we also examined different off-the-shelf hardware and its capabilities of supporting a natural, tangible whiteboard and sticky note feeling. We found that most of the deployed devices had different advantages and disadvantages. Additionally, the devices our participants favored depended on personal preferences. For the digital whiteboard hardware, the opinion was almost split as to which of the two boards participants would choose for design thinking activities; see Figure 4.7 (on average the display board scored 3.35 points (SD=1.50) and the projector board 3.2 points (SD=1.24)). In the usage statistics from server logs, we found more whiteboard events for the projector board (35973 vs. 22558 in total). Also, when we compared the activity for each team, four out of

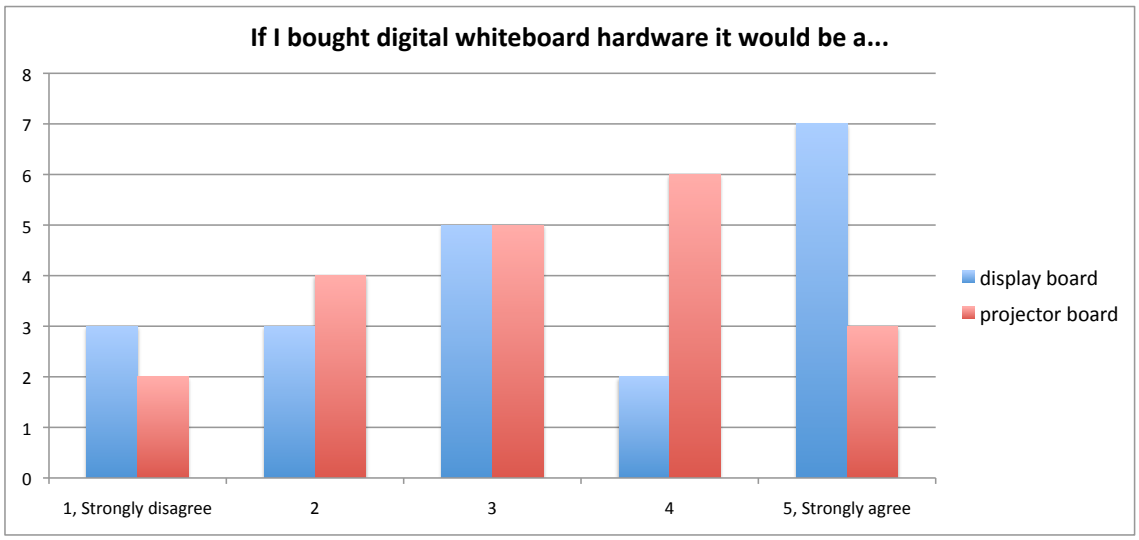

Figure 4.7: Comparison of digital whiteboard hardware. Participants did not have a clear preference for one of the two boards.

the five teams had more whiteboard events on the projector board (average no. of events per team: 7195 projector board (SD: 4958), 4512 display board (SD: 1735)).

The display board (SMART Interactive Display 6052iB) has the advantage of a high resolution (1920x1080px), displaying a large amount of content very sharply without the noise of a projector. On the other hand, the touch input was not comfortably usable: it often happened that the display received touch events from the bent fingers when writing with a pen or from the clothes at the wrist of the users. Our users also stated that it felt strange to move around sticky notes on the plain surface of the LCD display, especially when the display got warmer after a while.

The projector board (SMART Board 680i2) had a more comfortable surface (like plastic foil) and because the touch input was realized by pressure, there were no accidental touches. Additionally, because of its size (77”), it conveyed the feeling of a real whiteboard, more than the 52” LCD display. On the other hand, it had a relatively low resolution (1280x800px) and it could not automatically distinguish between hand, pen and eraser input. That is to say, all pens and the eraser tool had to be in its tray in order to switch to the move mode. During intensive project work with different users, this often led to unwanted pen strokes or confusion of mode switching in general.

As to the different sticky note devices, the iPads were very much appreciated because of their mobility and the simplicity of the sticky pad app. In contrast, the TabletPC was considered too heavy and therefore not mobile enough. The ability to write sticky notes with the keyboard via the web portal was appreciated by some participants, as this text was more readable than the handwritten notes, see Table 4.2. On the other hand, being visual, i.e. drawing something, was important to all teams, so they preferred the pen-based tools. Some participants explicitly noted that they liked the haptics of paper and thus liked the concept of a digital pen for writing sticky notes. However, the digital pen receiver had to be connected to a computer with a cable and this decreased its mobility and flexibility, which was a problem for the workflow. Half of the participants did not try out all of the different

Table 4.2: Number of sticky notes created with the available devices. We provided four iPads, one TabletPC, one Digital Pen connected to a laptop, and one laptop for writing sticky notes with the keyboard.

	iPad	TabletPC	Digital Pen	Keyboard	Total
Team 1	220	0	6	8	234
Team 2	138	2	1	2	143
Team 3	173	1	0	3	177
Team 4	134	6	8	37	185
Team 5	96	0	2	21	119
Mean per device	152.2	1.8	3.4	14.2	171.6
SD	46.69	2.49	3.44	14.82	43.84

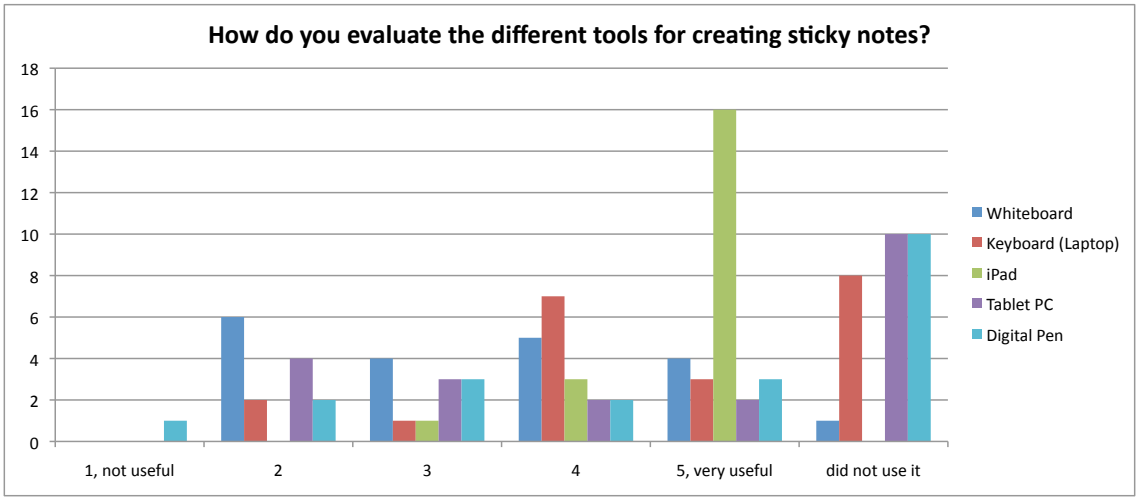

Figure 4.8: The iPad was the most favored tool for creating sticky notes. The Tablet PC and the Digital Pen were not used by half of the participants although all tools were introduced and tested.

devices, however, probably because the iPads worked so well for their purposes (see Figure 4.8).

4.3.6 Suitability for Design Thinking Projects

In the Likert-Scale section of the questionnaire we asked the participants to rate if Tele-Board was ready to use for DT projects. Though participants could well imagine using Tele-Board for other DT activities, the majority was unsure if it was ready to use yet, see Figure 4.9 (left mean: 4.25, SD: 0.64; right mean: 3.15, SD: 1.04).

As stated before, the hardware equipment also played an important role in the general experience of digital design work. In the free-form text fields, one participant stated that the Tele-Board was not yet advanced enough for real project work:

> It was a great experience working with the Tele-Board, but in my opinion it's not yet advanced for the D-school needs. It was a little too slow and reduced

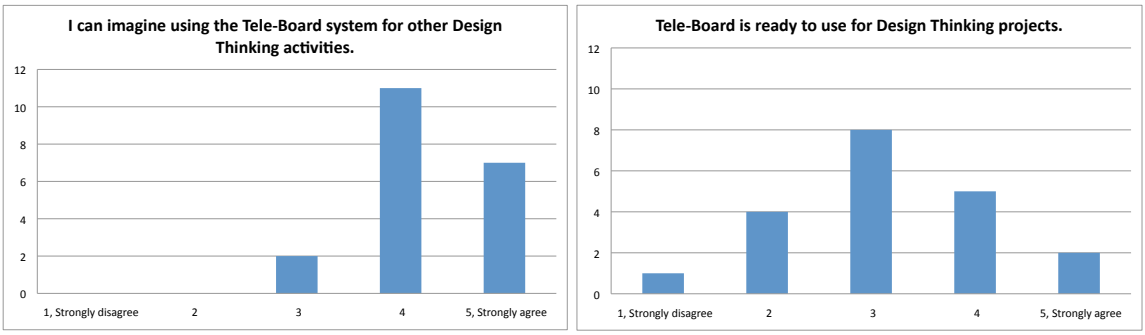

Figure 4.9: Evaluation of Tele-Board's usefulness for design thinking projects. Although users could imagine using Tele-Board for other design thinking activities, they were not sure if it was ready for projects yet.

> the teamwork since just one person could write on it. I also didn't feel that encouraged to be visual because I was too overwhelmed by the technology and a little afraid of making a mistake.

When we asked for the most valuable functions of Tele-Board, several people mentioned the possibility to collaborate from different locations.

> Design Thinking over distance, because it seems to be really possible, no alternative.
>
> I really think it's a wonderful thing, incredibly valuable for projects with people who are not in the same place. It just needs some adjustments to be a very good and important tool.
>
> If it was a little bit faster and more than one person could work on the same board, then it would be really fun. I would have liked to work in different locations (separated), to get to know the real values of the board.

4.4 Discussion

When comparing traditional and digital tools, participants came to different conclusions. Some were very satisfied with the digital environment and claimed that it was even better than the traditional whiteboard and sticky notes. They appreciated that they could easily add digital information and had a digital medium for future uses. In contrast, other participants stated that the digital tools would slow down their work. In the beginning, this was because they had to get used to the software and hardware. Afterwards, it was because there was no multi-touch at the whiteboards and only one person could work at a time. They also mentioned that writing on the digital boards was not as fast as writing on traditional whiteboards. However, these disadvantages were mainly due to hardware problems, and in a few years, they may disappear. Newer models of digital whiteboards already have improved substantially compared to the models we used. We could alleviate the missing multi-touch problem by providing sticky note devices for every user. This way, all users could contribute their input simultaneously. Some participants stated they even considered it an advantage that there was one "moderator" who stood at the whiteboard and coordinated the input.

In this study, we have shown that creative work in an all-digital environment is possible and good results can be achieved. Small changes in the interaction design of the software are necessary to improve the ease of use. We already implemented these changes based on our observations and the participants' feedback. If digital whiteboard hardware improves further, the barriers for digital design work can be removed to a large extent. However, especially good whiteboard hardware is expensive and difficult to transport. Moreover, digital equipment – particularly the sticky note devices – must be handled with care: if a paper sticky note pad falls down or someone spills coffee over it, it is not a big problem; for an iPad it is. Furthermore, a lot of people stressed that they liked working with paper and getting away from their computers if possible. On the other hand, we learned that people also liked to save paper and use digital pictures instead of printing them. Additionally, they appreciated the automatic saving of whiteboard content and the possibility of going back and forth in its "history". Another reason for using the digital tools – stated by users who were rather skeptical – was for geographically dispersed teams, as there is no real alternative.

4.5 Summary

In this chapter, we presented a study on the use of a digital environment for UCD / DT work. Teams used to the analog way of working evaluated how much the digital equivalents were useful during a DT challenge. Some users were quite enthusiastic about a digital DT environment because they generally preferred digital tools over their analog counterparts. Others still preferred the analog tools, also because they were happy to get away from the computer they use daily in their work.

Users found that Tele-Board was surprisingly similar to traditional tools. However, the digital hardware hindered teamwork because it did not provide multi-touch capabilities, and the input was too slow. Therefore, the majority was not sure if Tele-Board was ready to use for DT projects. Furthermore, if it was just a substitute for analog tools, users did not see enough added value in using it. Several people recognized the added value for remote work, because there was no alternative. Others told us that the small features, such as recoloring or copying sticky notes, or standard digital advantages, such as automatic saving and search functionalities, provide the added value they seek in a digital tool. At the same time, they also saw the greatest value in the possibility to work across different locations.

5. Distributed User-Centered Design Work

Collaborative work over distances is common practice for most employees of large global enterprises (Koehne et al., 2012). Many meetings include participants from multiple locations worldwide (Espinosa and Pickering, 2006; Hinds and McGrath, 2006). Although a variety of tools for supporting different working modes exists, the most commonly used tools are still audio conferences (for synchronous communication) and e-mail (for asynchronous communication) because they are readily available and easy to use (Matthews et al., 2011; Tang et al., 2011).

However, if companies want to use UCD activities, these ways of working are not well supported by standard tools. Collaborative brainstorming or sketching ideas on a whiteboard is difficult via e-mail or audio conference. As these ways of working are becoming more and more prevalent, even in larger companies (Martin, 2009), tools for creative work over distances are needed.

This chapter will show how Tele-Board was introduced in a global IT company and how it was and still is used by different teams in several countries. In the beginning of 2012, the first team started to use Tele-Board for their team work between Germany, Italy, and India. After three months, we conducted interviews with users from all locations and analyzed the usage statistics logs. I will present our findings on how team members at the different locations used Tele-Board and the benefits they saw in integrating it in their daily work. One year later, Tele-Board was used in other teams in other countries as well. I analyzed the usage behavior of new and former users in another round of 22 interviews. The focus of the analysis lies on the main reasons for using Tele-Board and user satisfaction with a digital whiteboard and sticky note application.

5.1 Introduction of Tele-Board in a Large Global IT Company

In 2011, a large global IT company started an initiative to introduce design thinking almost company-wide. In general, the goal was to use a “human-centered approach

to problem solving that helps people and organizations become more innovative and more creative," (Brown, 2009). After seeing a demonstration of Tele-Board, a team manager at this company decided to use it for his new team working between Germany, Italy, and India.

For his team, the manager had two incentives to apply design thinking and to use Tele-Board. Following the corporate strategy, he wanted his team to work in a more user- and customer-centered manner and be more creative in general. Additionally, he was looking for a way that his distributed team could work together more closely and make use of their diverse cultural backgrounds in addressing different markets. The first difficulty was that team members were in three different locations and two time zones. Additionally, the team was recently established and consisted of people who did not know each other earlier. The members also brought different levels of expertise with them regarding their new tasks.

As part of an IT company, the team's job was to create pre-configured parts of a larger software that would be ready to use at once by the customer. Though some software adjustments had to take place, most members of the team never did any coding. While some were involved in coding, others worked exclusively on general configuration, documentation, or translation. In their meetings, it was very important to make arrangements with each other to coordinate tasks. All team members worked on several pre-configured software parts at any given time. This work also involved people from outside of the team, some of whom were located in other countries, e.g. China, or the United States. There was a biweekly global team meeting where organizational topics and new ideas were discussed with the manager. Before our study, the team used video conferencing as the means of communication in the global team meeting and oftentimes they also used a desktop sharing application.

5.1.1 Setup and Study Context

Although the manager saw a demonstration of Tele-Board with digital whiteboard hardware and acknowledged the advantages of it, he told us that he could not provide this hardware at each location and that it was also not realistic to reserve the same meeting room (with this hardware) each time. Therefore, he wanted his team to start using Tele-Board with their standard laptops.

In this first phase, Tele-Board was used by a team of 25 people (13 female), with 15 of them located at the company's headquarters in Germany (DE), 2 in Italy (IT) and 8 in India (IN). While no team member had English as a first language, it was the language used in meetings. The team members came from different academic backgrounds. This resulted in teamwork that was quite interdisciplinary. During the course of our study, 5 people from other departments joined the team. On average, the length of service with the company was higher for the German team members (on average 13.5 years) than those from India (avg. 6.3 years) and Italy (avg. 8.5 years). Differences in expertise and addition of new members to the team necessitated knowledge transfer across locations.

5.1.2 Challenges for the Team

Two months before Tele-Board was introduced, we conducted interviews with 6 people out of the team (2 female, 4 male; 4 Germans, 2 Indians) for about 30

minutes each. We wanted to find out more about their current challenges with regard to global teamwork and what they expected from a more creative way of working and from a new tool.

Working in a newly created team with three different work locations and various levels of expertise, was viewed as a challenge by the members. Thus, with new working methods and a new tool they expected to improve international collaboration and teamwork in general. They wished to work in a more user-centered way, and with the introduction of design thinking, they hoped to get in touch with more stakeholders involved in creating pre-configured software packages. As these packages are sold worldwide, they saw their diverse set of knowledge and contacts in different countries as an opportunity for building better solutions. However, from collaboration on past and present projects they knew that distributed collaboration was not always easy. Although two interviewees said that they could clarify some issues over the phone or via instant messaging, others saw calling their remote colleagues as a hurdle:

> Perhaps it's the distance and the time difference, but you don't just pick up the phone and say: I have to tell you an idea I just had. That just doesn't work. I mean, you don't want to steal someone's time with any vague idea. (DE7)

With co-located colleagues, one could just walk by the office and see if the colleague had time. This was not always possible, however, if the colleague keeps different working hours. As also reported by other researchers (Espinosa and Pickering, 2006; Tang et al., 2011), time zone differences were a "major pain point" (DE3) in collaborative work. However, the team we studied saw it as an advantage that they needed to deal with only two time zones with a time difference of less than five hours. In fact, they hoped to leverage the longer time span of working hours.

Another difficulty for the communication between locations was language barriers. As mentioned, no member spoke English as their first language, therefore every member spoke with an accent. This could be hard for others to understand and consequently lead to misunderstandings. The same was true for formulating ideas and thoughts in another language:

> When you have an idea or want to say something spontaneously in another language, you first have to think: now, how do I phrase this? And this is not only our problem that we have to speak English, it's the same for people in India and Italy. Nobody can speak their first language and I think this is indeed a little handicap. (DE7)

Especially the topic of idea generation and collecting the points of view from people with diverse backgrounds and countries is seen as a great advantage of global teamwork. However, the interviewees said that this is difficult over distances with their current tools. Of course, standard office applications can be used, but the coordination is difficult and they cannot share ideas outside of these applications:

> We had a meeting two weeks ago with a colleague at another location in Germany. While one was drawing something on a whiteboard, the person who was not in the room was lost, because he could not follow the sense of the discussion. (DE3)

As underscored in this example, informal collaboration is generally poorly supported in current systems (Gutwin et al., 2008). However, it was quite important for the team, because they needed to "get the new colleague on board" (DE4) and this often happened via informal exchanges within or between adjacent offices:

> The state of knowledge is still very different. I'm quite new in the team, and the colleagues in India and Italy are as well. But I am lucky that I'm here in Germany, and there are many people who have been here for a longer time and really know a lot. No matter if it's about organizational stuff or domain knowledge, I have it directly at my office and that's really convenient. (DE7)

How much and in which way Tele-Board could fulfill the stated expectations of the team and their manager and support distributed collaboration in their office setting was examined via server logs and interviews after three months of use.

5.2 Evaluation after Three Month of Use

Tele-Board was introduced to the team in a workshop at the beginning of February 2012 where all of the functions were shown in detail and the participants could practice using them. The team then started to use Tele-Board during their daily work. An analysis of usage patterns based on server logs follows in the next section. Afterwards, the findings from interviews with most of Tele-Board's users are described.

5.2.1 Usage Statistics

To create the following diagrams, we analyzed the log file data from February 13 until May 11, i.e. twelve weeks. Twenty-five members of the team (15 from Germany, 8 from India, 2 from Italy; 13 female, 12 male) had user accounts, though 5 of them (DE9, DE10, DE11, DE15, IN8) joined the team only after about 6 weeks.

In the first three weeks, only three to four people used the systems, but in the following weeks more and more users were involved and whiteboard events increased. During Easter vacation in Europe, the number of users dropped, but afterwards we saw a continuous increase of users and whiteboard events again.

5.2.1.1 Working across time zones

Time zone differences can be a challenge for teams at different locations. But as Tele-Board also supports asynchronous ways of working, we were interested in the distribution of working hours. Figure 5.1 shows the aggregated number of users for every hour of the day for the entire 12-week period. For example, we can see that all users in India had worked with the system between 12:30 pm and 4:30 pm local time at some point during the study period. Between 8:30 am and 9:30 am IST at least half of the Indian users connected to the system one or more times.

The team mostly followed the pattern of typical working hours from about 9am to 5pm local time. Apparently, the overlapping synchronous work time was used more intensively than time spent working alone. This often meant that the Indian team members were working until 6:30 pm or longer. In future research, we want to investigate if this intense synchronous use can also be observed in teams that have fewer overlapping working hours. We expect to see more asynchronous work because it is likely that people prefer working during the standard office hours at their time zone, as we can partly see with the Indian team members.

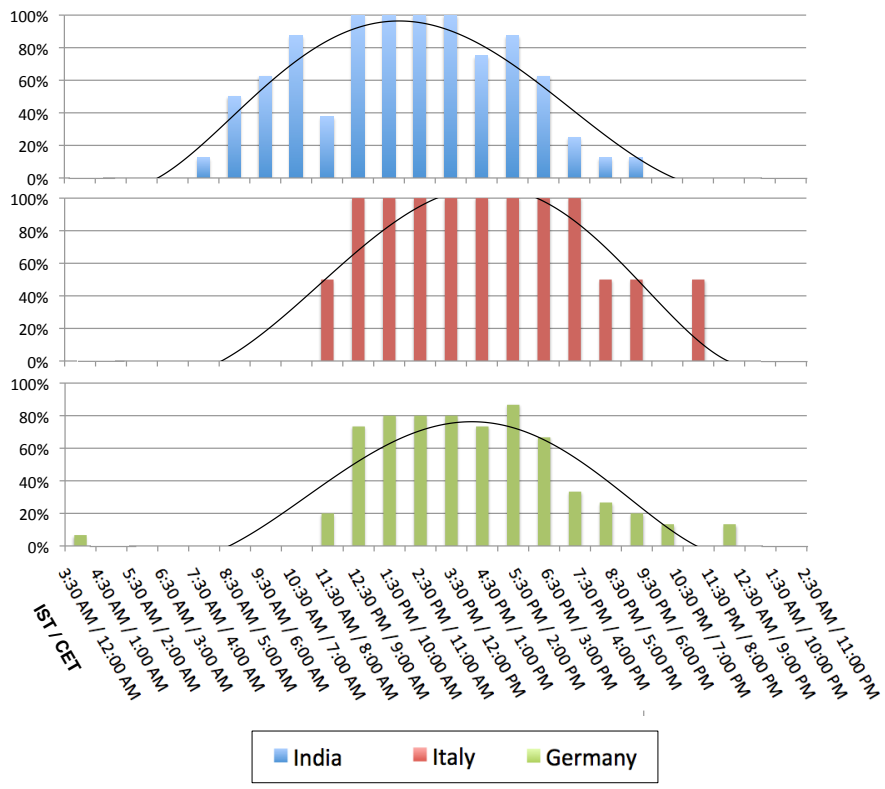

Figure 5.1: Distribution of user involvement throughout the hours of the day and over the whole study period. Locations are distinguished by colors; the two involved time zones are Central European Time (CET) and Indian Standard Time (IST).

5.2.1.2 Different usage patterns

Figure 5.2 shows a selection of panels and how they were used from week 4 until the end of the study period. The size of the circles indicates how many users were involved each day, and the colors show the location of the respective users.

The interactions on the panels reveal different usage patterns. It seems, for example, that panel 590 was used for long-term feedback collection. In contrast, Panel 589 appears to have been used primarily as an idea sketchpad during a single meeting. After this point, however, it only served to document meeting recap (see "Results from Interviews" section for more details). Looking at the different panels, we can see that there is no single way of working with Tele-Board; rather people shifted between working alone, in small groups, and in larger groups. They used the panels during different time periods and manipulated the content asynchronously as well as synchronously.

Giving users the possibility for easy transitions between working together and alone in order to facilitate "loose and tight coupling" is important for distributed groupware (Gutwin and Greenberg, 2002). Our users also appreciated that Tele-Board not only provided one way of working but several (see *Support for Different Ways of Working*).

As an indicator of collaboration among Tele-Board users, we examined how many people worked with the same content, i.e., the same sticky notes. It turned out that almost half of all sticky notes created during the study period were moved/modified

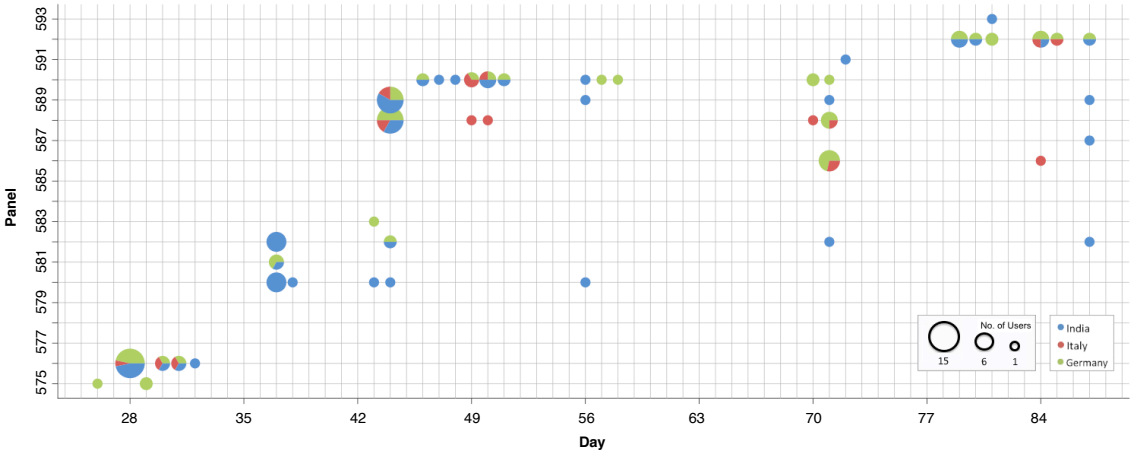

Figure 5.2: A selection of panels and their user involvement structure over time. The size of each circle displays the number of active users at a certain day on a certain panel. The colors indicate how many people from different locations collaborated with each other. Some panels were only used in a few synchronous global team meetings while other panels were only used by a few participants asynchronously.

by at least 2 people over the course of the study, with the highest number of users editing as many as 8 sticky notes (average: 2.08, SD: 1.44).

5.2.1.3 Activity per location

The most interesting fact we could derive from the log data was that the activity of all Tele-Board users was not evenly distributed across the different locations (see Figure 5.3).

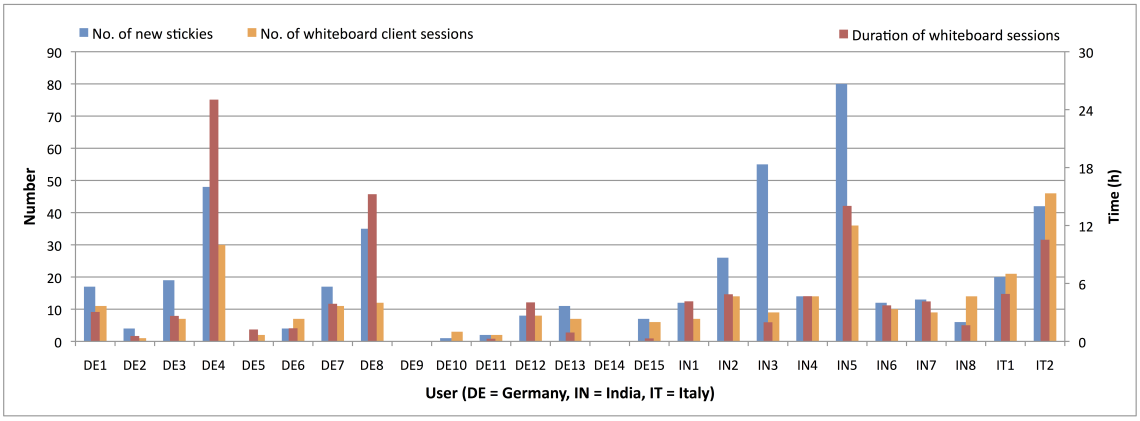

Figure 5.3: Activity of all Tele-Board users. The left y-axis indicates the number of whiteboard client sessions (orange) and the number of created sticky notes (blue) per user. The right y-axis and the red bars show how many hours each participant used Tele-Board within the three months of our study.

For all interactions with the system – number of sticky notes created, number of whiteboard events, number of whiteboard client sessions, and session duration – were higher for users at the company's subsidiaries in India and Italy. Although there were some very active users at the headquarters in Germany, others contributed

Table 5.1: Average, median, and standard deviation values for all activities with the Tele-Board system per location for the study period of twelve weeks.

Location		No. of sticky notes	No. of whiteboard events	No. of whiteboard sessions	Session duration (hours)
DE	AVG	11.5	181.7	7.1	4:30:18
	MED	7.0	108.0	7.0	1:21:00
	SD	14.0	230.9	7.5	7:20:49
IN	AVG	27.3	651.4	14.1	4:54:30
	MED	13.5	129.0	12.0	4:08:30
	SD	26.3	1225.4	9.3	3:52:19
IT	AVG	31.0	803.5	33.5	7:43:30
	MED	31.0	803.5	33.5	7:43:30
	SD	15.6	675.3	17.7	3:58:18

little or nothing. However, four of the five new users who joined the team after half of the study period are located in Germany. This difference in contribution is also reflected in the median and standard deviation values of the different activities (see Table 5.1).

Because the length of service with the company in Germany is higher on average, we examined whether there is a relationship between the length of service and Tele-Board activity (see Figure 5.4).

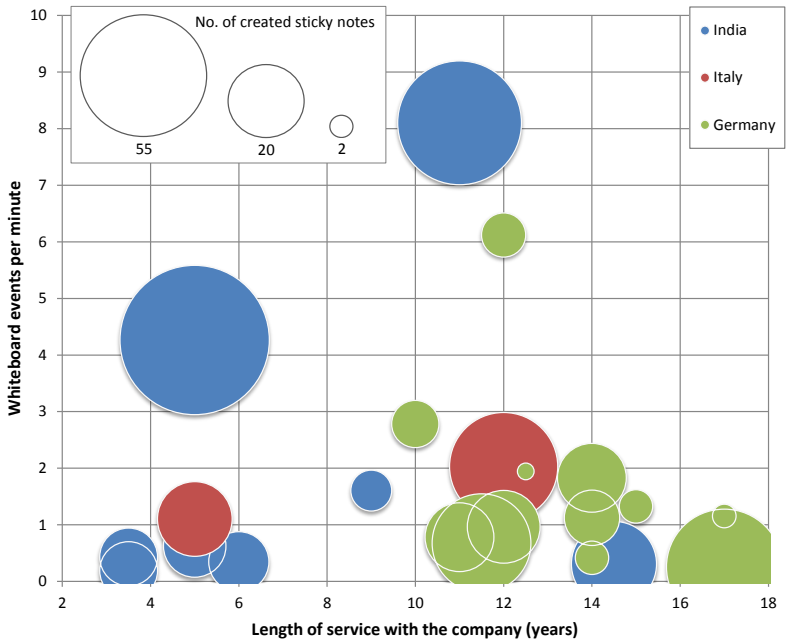

Figure 5.4: The level of activity of all Tele-Board users opposed to their length of service with the company. Each user is represented as one circle. The number of sticky notes created is expressed by the size of the circles. Based on their location on the y-axis, the circles also show whiteboard activity in terms of whiteboard events / session duration.

In this figure, the size of the circles shows the number of sticky notes a user created (each circle represents a user). The y-axis indicates the ratio between whiteboard events (i.e., every interaction with the whiteboard client) and session duration (i.e., whiteboard events per minute). This shows how active users were after starting the whiteboard client. Please note that three German users do not appear in this figure because they did not write any sticky notes. Though the statistical values in the table show that the German users generated fewer whiteboard events, started the whiteboard client less often, and wrote fewer sticky notes, a lot of them used the whiteboard actively once they initiated a session. This is indicated by the ratio of whiteboard events per minute. However, we saw no relationship between activity and length of service with the company.

We believe that the main reason for the variation in Tele-Board use across locations is based on the difference in potential benefits, as described by Gutwin et al.'s study on informal collaboration (Gutwin et al., 2008). As mentioned by user DE7 in the *Challenges for the Team* section, there are many domain experts at the headquarters and the German users can meet them informally on the floor or go to their office with a question. Therefore, the benefit of using Tele-Board is not as high at the headquarters as it is at the subsidiaries and maybe not "worth the effort of initiating and joining into a collaborative session" (Gutwin et al., 2008). Especially with regard to knowledge exchange, users at the subsidiaries see Tele-Board as a place where they can ask questions and discuss them. Instead of spending time writing e-mails, users saved time by utilizing Tele-Board instead. As the analysis of the interviews in the next section shows, the difference in activity across locations corresponds to the differences in opinions on the usefulness and effectiveness of Tele-Board.

5.2.2 Results from Interviews

In May 2012, we conducted semi-structured interviews with 20 members of the team (10 male and 10 female). 11 interviewees came from Germany, 7 from India, and 2 from Italy. As 4 interviewees (DE9, DE10, DE11, IN8) were new to the team and did not use Tele-Board yet, they talked about their first impressions and experiences from former collaborative remote work. Each interview lasted approximately 30 minutes. Interview questions focused on the usage of Tele-Board and general communication within the team and with stakeholders outside the team. The interviews with the German interviewees were conducted face-to-face, while the interviews with team members from India and Italy were conducted over the phone. All interviews were recorded and transcribed. We used open-coding techniques to discover patterns and recurring topics (Corbin and Strauss, 1990). The main topics identified in the analysis are described below.

5.2.2.1 Support for Different Ways of Working

In response to our query regarding the use of Tele-Board, the interviewees said that they used it primarily during team meetings in the phases of generating ideas / brainstorming and collecting feedback. All users created sticky notes in the same way: in the web portal by typing the note's content with their keyboard (see Figure 3.4). Users liked Tele-Board for idea collection in particular, because it worked "just like a whiteboard; a virtual one, as it is intended" (DE6). For synchronous work, the team members typically did a silent brainstorming and afterwards discussed and grouped their ideas:

> Normally we have a topic for the meeting, and we agree with the participants to allow some time to post the ideas on the board and then we go back into an all-together mode. Normally these are remote, of course, so we are not sitting in the same room anyway. Then we rearrange the ideas on the board and we start sharing and commenting and working on the ideas that are already posted on the board. (IT2)

Ten out of the sixteen active users told us that they also used Tele-Board for asynchronous work. DE4, for example, first posted his ideas on a whiteboard panel and later presented them in a project team meeting to other stakeholders. In most other cases, a meeting organizer created a panel and sent the link to it with the meeting request, asking all participants to post agenda topics or questions on sticky notes. In the meeting, everyone opened the panel and went through all topics on the notes. Feedback collection could occur the other way around, i.e., someone created a panel during a meeting and all participants were asked to post their feedback after the meeting (see Figure 5.2). This transition between different ways of working (Tang et al., 2009) was not available in the other tools the team was using and was greatly appreciated.

5.2.2.2 Influence on Efficiency

In the former section, we saw that the team used Tele-Board for idea generation and communicating synchronously and asynchronously. But, as in the case with all new tools a company implements, the real question is how efficiently the tool supported employees in their daily work. Though we uncovered different points of view, half of the interviewees stated that Tele-Board saved them time because more people could work together simultaneously. Because of this, meeting minutes and documentation could be omitted and e-mail correspondence could be decreased.

> Earlier we used to just have an open discussion where anyone who has an idea on a particular topic, gives his or her ideas, and the minutes are taken by one person and finally at the end of the meeting all ideas discussed are sent out as minutes by this person; which is time consuming, it's additional effort for a person to capture the ideas, put them in minutes and send it out. And not all of them speak up during a meeting if they have some ideas. Some of them tell their ideas, some of them don't. [..] Now that we are extensively using Tele-Board for idea collection, I find that the time for those exercises has drastically been reduced. Because everyone just puts in their ideas and it just takes 2 min. and then it's already in there. Now the person who is hosting the meeting only needs to collect the ideas and put it in a proper grouping. The tool has improved the idea collection phase. (IN2)

Interestingly, we heard such statements from only two people located at the company's headquarters. Additionally, eight out of the nine interviewees who worked at the subsidiaries said that Tele-Board saved time. This shows that the benefit of Tele-Board was considered higher by the Italian and Indian users and corresponds with the usage statistics of more activity at these locations (see Figures 5.3 and 5.4).

Most interviewees agreed that there were situations when it was neither efficient nor helpful to use Tele-Board. Such situations included one-on-one phone calls, short

meetings where to-dos were discussed (IN1, IN7), as well as document review and project status meetings (IT2, DE2). As the tasks of all team members within their project were diverse (DE6), some interviewees told us that they rarely had meetings where they could "think out of the box" (DE2, DE5, DE6) and the use of Tele-Board could be beneficial.

Conversely, other users saw no advantage to using Tele-Board when compared with existing tools (DE2, DE5):

> I don't see the added value. Basically it's another tool for making notes. I prefer having a list and all of these sticky notes are just too much information for me if no one groups or categorizes them but just sticks them there. You always need someone who sorts them. I prefer having it structured. I prefer a list that I can work from. Otherwise I have to read everything first, then structure it and that's cumbersome. (DE5)

In general, there were different points of view as to how much Tele-Board could and should help structure a meeting. Some thought it helped structure brainstorming and idea grouping (IN3, IN7, IN8, DE7, IT2), while one user criticized what he saw as the unstructured format of the meeting (DE3) and yet another thought it was good to have more flexibility (DE1).

Some users saw advantages in the asynchronous work as time zone differences could be bridged and it was easier to go on working at a whiteboard panel at any point in time (IT2, DE1, IN1), see Figure 5.1.

> Sometimes it helps when you are working with colleagues from other locations and you have been doing some tasks and they have to follow up, because of the time difference it's always better you use the tool and you post what you have completed, so you don't wait. Because we have to wait until the German colleagues come in the afternoon. Instead we can just start in the morning, based on what the German colleagues or others have posted. That might help in going faster. (IN1)

Another point where users told us that Tele-Board saved time and effort was with respect to the "clean desktop" policy of the company: all employees are expected to wipe off whiteboard content or take away flip-chart sheets in the office. This was not necessary with a virtual whiteboard (DE1, DE11).

5.2.2.3 Influence on Communication and Collaboration

Though some interviewees perceived that the communication within the team was already very good (DE6, IN2), others saw further improvements due to the use of the new tool. For example, one user found that the tool was advantageous for quieter people. The possibility to communicate was easier when it involved posting a sticky note and explaining it afterwards (DE7). In general, several people agreed that Tele-Board encouraged communication (IN1, IN2, IN7) because people were more comfortable speaking freely (IN5) and lost any inhibitions to say something if they could post it first (DE4, IT1). Especially for asynchronous feedback rounds,

participants liked the "anonymous" appearance of sticky notes, even if it was possible to track the author of the sticky note.

Having everybody's input in *written* format was important to many users (DE11, DE3, DE5, IN6, IN7, IT2). It helped them to remember ideas and to improve understanding of what team members wanted to say. As mentioned in the beginning of this chapter, problems with audio connections and accents of non-native speakers sometimes hampered communication (IT2, DE5, IN7). This is consistent with the findings of Yankelovich et al. (2004). In such cases, written sticky notes assisted in communication:

> When we talk over the phone, it might be that their voice is not clear and we could not understand them properly. In that case Tele-Board was very helpful because we have written format and we get to see what they really want to tell us. (IN7)

Overall, the manager of the team also saw an improvement in mutual understanding:

> The understanding is definitely better than before. I mean, I see their results. And when I talk to them separately at regularly scheduled meetings I can tell that they are talking less about different things. The big picture is more consistent. It's better, but not perfect. (DE8)

5.2.2.4 Interplay with other tools

Tele-Board offered a new way of working, and the whiteboard and sticky note metaphor was different from other digital tools used in the company. It was our goal to introduce a virtual whiteboard for remote collaboration which was, as one user described it, "a perfect addition to the other tools" (DE6).

As the team formerly used MS Excel for collecting ideas and feedback, some interviewees compared Tele-Board to this tool. One user expressed the feeling that she used it like she used Excel, just with easier clustering (DE7). The team saw the main difference and advantage as the ability to enter data simultaneously or in "real-time" (IN1, IN2, IT2). Others thought it was easier to use than other tools because everyone knew the analog equivalent, and it was more fun to use because of its colors and playful character (DE4, DE1).

> [..] it's very receptive, because it's colorful, it's sorted, you can concentrate on the visuals, and that's easier to remember than words on an Excel sheet. We did it with Excel before, and the rows and columns don't stick in your head. But if you remember the colorful stickies you can say: yes, the pink topic was below the orange one, it stays into your head as a picture. (DE1)

Regardless of whether people liked working with whiteboards and sticky notes, we often heard that they had to transfer the content into an MS Office document. As the manager put it: "It's good for collecting ideas as a first step towards a solution. But it has to go on..." (DE8). Tele-Board content could be exported as "a mind

map where it is easy to add links and documents" (DE8) or as some participants stated: "a Powerpoint slide-deck" (IN2, DE5, DE6).

We also asked the participants how much they used video conferencing for their remote work. Most of them said that they usually did not use it for their project work, because it was difficult to get a video conferencing room at each location. For this reason, especially in the case of small meetings, video conferencing was seen as not worth the effort. They also said, it was not very important to see the faces if they saw the same content on the screen (IN2, IN6, IN8, DE4, DE5, DE6, IT1, IT2). One user thought it could even have a negative effect during brainstorming because the faces are distracting (DE3), which is consistent with other research (Brubaker et al., 2012).

5.2.2.5 Tool Introduction

Introducing new tools in a corporate environment is challenging because employees do not have much time and are compelled to learn several new tools, especially at the beginning (DE2, DE9).

In our case, the manager of the team promoted the use of Tele-Board from the beginning (DE8). Some team members accepted it passively (IN8, DE3, DE6) while others viewed it negatively, "I think a lot of people use Tele-Board because our manager wants it" (DE2), or positively, "It is good that our manager forces us to use it, someone has to convince the others" (DE9).

Several users saw it as an advantage that the use of Tele-Board was not difficult to learn (DE6, IT1, IN8) and that new users could start working right away after they understood the main features. These features were: creating sticky notes and adding them to a board, changing the color of sticky notes, creating clusters, creating a panel, and starting a project. We heard from the new team members that it was not too difficult to learn how to use Tele-Board (DE11, IN8).

Members of the team thought that they could get feedback from other stakeholders (e.g. product owners or consultants) more easily and on a regular basis if these stakeholders also had a Tele-Board account (IN1). As the tool was only introduced to team members, no automatic routine for creating other users was set up. However, Tele-Board could certainly help in collaborating with people outside the company. As the manager put it:

> In a world with less budget and possibilities to travel to a customer, a platform for quick exchange is very valuable. It may help to get a quicker understanding for the customer's needs. (DE8)

5.2.3 Findings from Usage Statistics and Interviews

From usage statistics and interviews, we can tell that Tele-Board became part of the team's repertoire of work tools during this three month study. Though the time they used it (in terms of session duration) may not seem to be high compared to their total working time, we detected whiteboard activity on 46 of the 60 working days (12 weeks of 5 days). Considering that main working time is dedicated to composing and building suitable software packages, we were happy to see that team

members included Tele-Board quite frequently in the range of tools for their internal communication and collaboration.

Interviewees stated they did *not* use Tele-Board for meeting types such as status updates, document review meetings, or one-on-one phone calls. For these kinds of meetings, existing tools in the corporate environment do the job, and Tele-Board does not aim to be their substitute. With Tele-Board, we provided the team with a tool that complements existing tools with new functions (DE6). Now they had the possibility to generate ideas and input at the same time, and they could continue working on the same content at a later point in time, whenever convenient.

Several users thought that Tele-Board saved time because it allowed them to work together in real-time without waiting for others to finish. Work was shared, which also meant that no one was burdened with writing documentation or minutes of the meeting.

We could also see that Tele-Board improved team collaboration. The manager confirmed that mutual understanding (e.g., of the project contents) increased when using Tele-Board. A second improvement was the feeling of shared experience and a sense of co-presence that working on the same whiteboard gave team members (Brubaker et al., 2012). The *written* format of sticky notes, in contrast to audio-only meetings, was another advantage for communication among team members because it mixed verbal and visual communication. Moreover, working with the same material simplified the verbal communication and made interaction more efficient (Gutwin and Greenberg, 2002). Our interviewees confirmed this and said it was easier to understand others and express one's own opinion. Additionally, quieter participants were more likely to be heard.

Of course, other tools also provide the possibility to share in written format, but they either do not support real-time participation (e.g. MS Office products), or they only show input in a linear format (e.g. instant messengers). With the help of sticky notes, Tele-Board gives the possibility of rearranging and sorting one's own input as well as the input of others. The team used this option for creating schedules and plans for meetings or for collecting questions they had for other stakeholders. Oftentimes, similar ideas appeared, but then they could be grouped together and a shared interest in this topic became visible. Additionally, sticky notes encourage going from structured meetings and data sharing to the "far messier tasks of generating ideas and building consensus around them" (Brown, 2009), which is desirable when a company wants to apply design thinking or similar methods.

Tele-Board combines the advantages of synchronous collaboration with the possibility of asynchronous input. Users could easily start working before a meeting or go on working after a joint session with their colleagues. From usage statistics and interview statements, we saw that the team actually followed such work practices (see Figure 5.2): some panels were mainly used for one joint meeting; others were used repeatedly over time. Additionally, entering ideas whenever they occurred made the team less dependent on different time zones and office hours (see Figure 5.1).

By complementing existing tools, Tele-Board offered a new communication channel that was used by team members, especially at the subsidiaries. Feedback from interviews and usage numbers from log files showed that users from Italy and India interacted more with Tele-Board than users from the headquarters in Germany (see

Table 5.1). As domain and task experts were located mostly at the headquarters, German users did not have the same motivation to use a digital tool for knowledge exchange as the Italian and Indian users did. German users could simply take a question directly to a colleague. By contrast, an Indian user told us that he and his colleague used Tele-Board to collect questions on a panel and then discussed them with more experienced colleagues in Germany.

We also learned that a prerequisite for using a tool like Tele-Board is easy availability to all team members. The manager told us that a whiteboard software tool available only on dedicated whiteboard hardware in special meeting rooms will not be used very often. If the hardware becomes available on a general basis, the Tele-Board software could support more similar work practices to those at traditional whiteboards. Nevertheless, it is essential that Tele-Board remains available to users on standard computers as well.

5.2.4 Summary of Three Month Study

From this first study after three months, we learned that the "optimal" system setup we created in our laboratory could not simply be deployed in a company as is. It needed to be adjusted to a user's daily environment and equipment, which meant standard computers instead of digital whiteboards and sticky note hardware.

However, users could still benefit from the system because it enabled them to engage in real-time idea generation and feedback sessions over distances. It also provided them with a platform for knowledge exchange anytime they wanted to use it. Tele-Board supports a smooth transition between synchronous and asynchronous work: a user can either work alone at a panel asynchronously or several users can connect to the same panel to work synchronously. Everyone could choose his or her preferred way of working, depending on the respective (team) situation. System log data and interview results showed that both ways of working were used by the team. It was therefore important that they were able to shift easily between working alone and working together.

Moreover, in the interviews we found that a shared workspace and its artifacts simplified verbal communication and understanding due to the written format of sticky notes. The graphic appearance of sticky notes made them ideal for arranging and sorting.

Interviews as well as log data showed that Tele-Board users at company subsidiaries used this extra communication tool considerably more than those at the company's headquarters. Tele-Board provided a potentially promising channel of communication to improve joint work across company branches.

5.3 Evaluation after 1.5 Years of Use

The first study described above, was based on the usage of Tele-Board between February and May 2012. After this period, the team continued using the tool for their work. Additionally, other users from other departments of the company started using Tele-Board because they had heard about the tool from members of the pilot team. Overall, in 2012 the number of new users was not very high, but in 2013, each month several new users joined the system, see Figure 5.5.

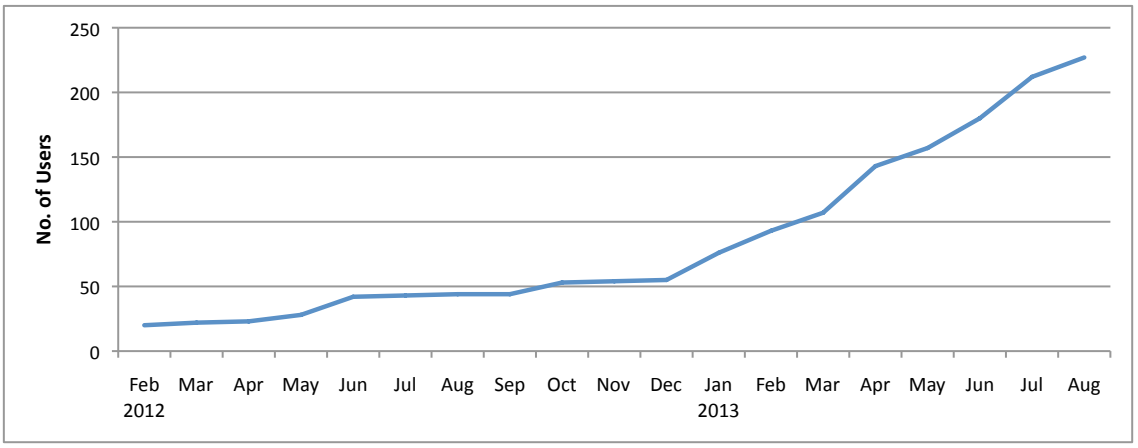

Figure 5.5: Development of new active users of the Tele-Board system in a company context over the course of 1.5 years

In the beginning of 2013, the manager of the first team became manager of another team in his organization. In February and March he introduced Tele-Board to his new team, which is distributed between the United States and China. The team consisted of 32 people, 16 in the United States and 16 in China.

After the introduction of design thinking to the company in 2011, the number of design thinking projects, coaches, and employees who had participated in a design thinking training steadily increased. In these design thinking projects, the teams conducted all activities of a design thinking process (see Chapter 2.1.1) and not only some of the activities, like the pilot team in the first study. In the beginning, all projects were conducted at one location with traditional whiteboards and paper sticky notes. The project teams were either comprised of people from one location, or people from other locations traveled to the design thinking project location. This way, they explicitly avoided remote collaboration for design thinking projects. However, due to budget and time constraints, it was not always possible to bring together all team members for the entire project period. Therefore, the teams had to work remotely and some of them used Tele-Board for this distributed work.

Approximately 1.5 years after Tele-Board was first introduced, we studied its use again. First, I will give an overview of the current users of the system. Afterwards, the findings from 22 further interviews with some of the first users and several new users will be examined.

5.3.1 Overview of User Groups and Activities

At the end of August 2013, there were 415 Tele-Board user accounts. Out of these, 227 users actively used the system, i.e. whiteboard activity was registered. Corresponding to the number of new active users (Figure 5.5), the amount of whiteboard events has also increased in 2013, see Figure 5.6.

The amount of activity varied among users, see Figure 5.7. About half of the users had only five or less whiteboard sessions and created less than 10 sticky notes. These users were probably only involved for one meeting or just wanted to try out Tele-Board. However, about 20% of the users had more than 25 whiteboard sessions and

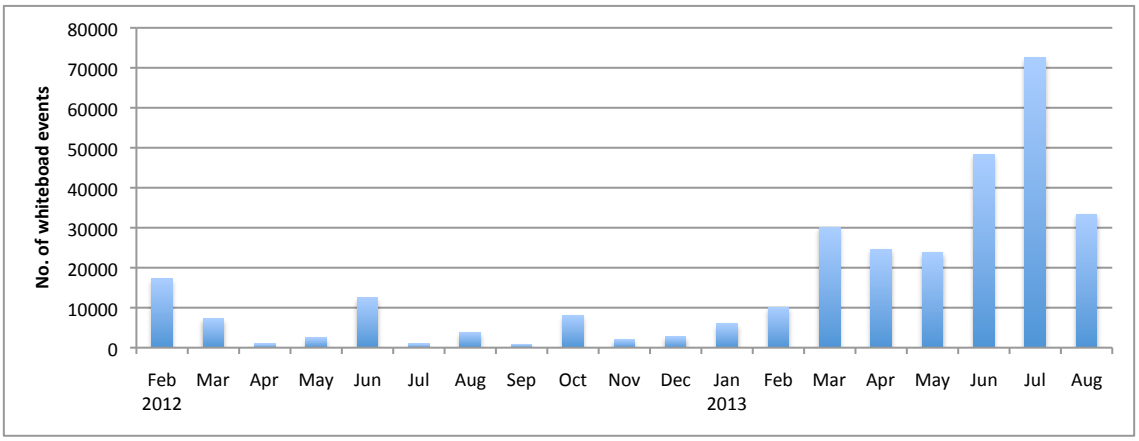

Figure 5.6: Activity of all Tele-Board users from the beginning in February 2012 until August 2013

over 50 sticky notes, and about 10% of all users had over 50 sessions and created over 130 sticky notes.

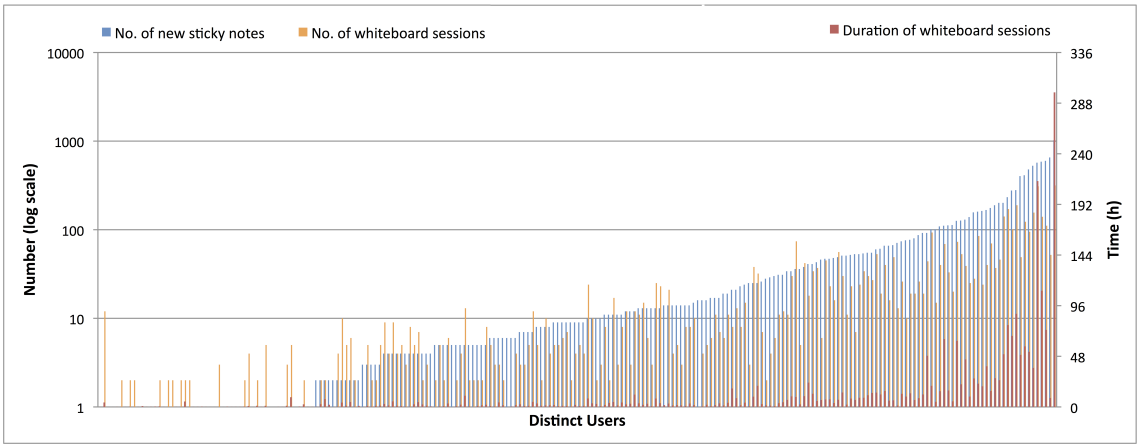

Figure 5.7: Usage patterns of all Tele-Board users with registered whiteboard activity (n=227) from the beginning of February 2012 until August 2013. Each kind of activity (no. of created sticky notes, no. of web sessions, duration of whiteboard sessions) is represented as one bar per user.

Tele-Board was used from several different time zones, as users indicated in their profile for the Tele-Board web portal: Europe UK, Europe Central, Asia India, Asia China, Asia Singapore, US Pacific, US Central, US Eastern, Americas Brazil. However, for the majority of new users, we do not know where they were located and from which time zone they were using the system. Many users did not change the default time zone (Europe Central), although they probably worked at another location. Therefore, reliable statistics on the activity between the different locations cannot be created from this information.

Yet, for the users who were part of the first study, it is possible to see how the activity between the locations has evolved, see Figure 5.8

Overall, the distribution across the three locations changed little. The relative amount of whiteboard events (amount of events per location divided by number

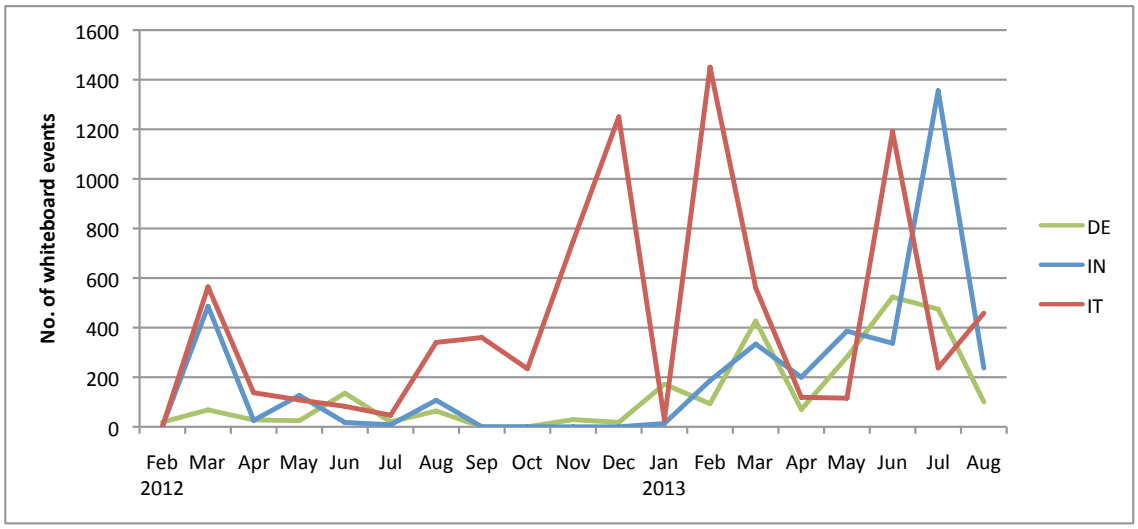

Figure 5.8: Whiteboard activity of the pilot team (average per user) from the beginning of February 2012 until August 2013. The general distribution across the three locations Germany (DE), Italy (IT) and India (IN) has not changed compared to the first three months of use.

of people at the location) in India and Italy was higher than in Germany for most months. Other activity values (number of created sticky notes, number of opened whiteboard session, and session duration) show the same distribution for average values per user, see Table 5.2. As in the first three months, the difference between activities for the German users still varies widely. Some users frequently interacted with Tele-Board while others hardly used it.

In order to know more about the way Tele-Board was used by previous users as well as new users, we conducted interviews with several users of different groups.

5.3.2 Interviewpartners for Second Evaluation

In contrast to the former interviews conducted with employees of one team, the interviewees for the second evaluation were from different teams with different expertise pertaining to Tele-Board. Overall, the goal of the interviews was to answer three main questions:

- How did the users of the first study continue using Tele-Board?
- How did new users learn how to use the system and in what way did they use it?
- How well does Tele-Board support the different design thinking activities compared to the traditional tools people are using at one location?

Regarding the first question we interviewed seven users from the first study (DE1, DE2, DE3, DE4, DE5, DE7, DE8). Among them were frequent Tele-Board users as well as infrequent users in the first study. We also interviewed the manager about his impression from the development of the first team, as well as the new team he introduced to Tele-Board half a year ago.

Table 5.2: Activities with the Tele-Board system of the pilot team over the course of 1.5 years. Average, median and standard deviation values are shown per user at the locations Germany (DE), Italy (IT), and India (IN). Similar to the values after the first three months (see Table 5.1), the values for the users at the headquarters in Germany are lower than those at the subsidiaries.

Location		**No. of sticky notes**	**No. of whiteboard events**	**No. of whiteboard sessions**	**Session duration (hours)**
DE	AVG	135.9	2706.3.7	63.2	6:36:28
	MED	63.5	777.0	40.0	9:43:32
	SD	193.7	4584.65	74.8	7:01:44
IN	AVG	183.6	4300.5	73.5	7:18:43
	MED	79.0	1231.5	49.0	13:26:59
	SD	180.2	4932.8	58.67	6:37:27
IT	AVG	217.0	8034.0	156.0	15:46:28
	MED	217.0	8034.0	156.0	15:46:28
	SD	22.6	5704.9	21.2	19:32:55

With regard to the second and third question, we interviewed different groups of users. The first group were users located in Germany and the majority of them (DE16, DE18, DE19, DE20) are design thinking coaches. They mainly give trainings in design thinking and support design thinking teams during their project work. One user (DE17) was part of a neighboring team and tried out Tele-Board with her colleagues. We only introduced user DE19 to Tele-Board's functions in a shared screen web session. All other users did not receive any training.

The second group of interviewees was located in the USA with three in Palo Alto (US3, US4, US5), one in San Diego (US2) and one on the East Coast (US1). All of them were working in the USA / China team with the same manager as the pilot team. Two of the interviewees (US1, US2) had already actively used Tele-Board before. Two other interviewees (US3, US4) had little experience with using Tele-Board, and US5 had not used it before.

The third group of interviewees was located in Shanghai, China. All of them (CN1-CN5) had some experience in using Tele-Board. None of them received any training in how to use the tool.

All interviews with users located in Germany were conducted face-to-face in the headquarters of the company in July 2013. The interviews with the US users were partly conducted over the phone (US1, US2) and face-to-face in the Palo Alto office in April 2013. The interviews with the Chinese users were conducted over the phone in August 2013.

5.3.3 Results from Interviews

All 22 semi-structured interviews lasted approximately 30 minutes and were analyzed with regard to the three main questions from the previous section. During the analysis, we learned that the way of using Tele-Board did not primarily depend on

the experience of the users, but rather on the way of working within their team and the tasks they had to accomplish. The different ways of using the tool are described in the next section *Different Ways of Using Tele-Board*. Afterwards, I will outline the *Advantages and Disadvantages of Tele-Board* compared to other tools available to the interviewees, including traditional whiteboards and paper sticky notes. As the majority of interviewees did not receive a Tele-Board training before using it the first time, their experiences are described in the third part *Introduction to Tele-Board and Ease of Learning*.

5.3.3.1 Different Ways of Using Tele-Board

The pilot team continued to use Tele-Board frequently during their global team meetings or to prepare these meetings. According to the interviewees, the way of using Tele-Board did not change much, it was just used more frequently, and it became a matter of course for certain tasks (DE1, DE4, DE5, DE8). The team's main use case was collecting ideas or feedback across locations. Afterwards the sticky notes collected were clustered and prioritized, either within a team meeting or by those in charge of the respective topic. Sometimes they invited other stakeholders, like sales representatives, consultants, or customers to the meeting, collecting questions for these people beforehand. Recently, the team also used "templates" for structuring the sticky notes more easily. For example, for collecting feedback, they divided a panel in four quadrants labeled positive, negative, ideas, and questions. Each user could then directly put sticky notes in the respective quadrant. Once created, they copied the empty template and used it in other projects. The initiative of creating templates was started by the manager, DE8, but other users also added new templates they considered useful.

Several users reported that they saw the main application area of Tele-Board for brainstorming in the beginning of a project, especially for a greenfield project when the focus of a project was discussed with colleagues at different locations (DE1, DE4, DE5). For this, everybody added ideas at the same time and structured these ideas together while communicating via an audio connection. The first users, as well as the new user DE17, also used Tele-Board asynchronously for collecting strategic topics for the future. They opened a panel where each could add ideas whenever s/he wanted. Similarly, they used it to create an agenda for an off-site meeting with the Indian and Italian colleagues. The main organizers created the agenda in a panel and others could add their comments. For several users Tele-Board was "the tool if you want to collect something" (DE1, DE4, DE5, DE8, DE17).

Besides this general use, Tele-Board was also utilized in dedicated design thinking projects. Normally, design thinking project teams work in special design thinking rooms with traditional whiteboards and paper sticky notes. These rooms are equipped with high tables and barstools as well as prototyping material. However, in distributed setups, most teams moved to standard meeting rooms because these rooms had audio and video conferencing capabilities. Some teams used Tele-Board in combination with audio conferencing only, others included video conferencing on an extra screen or projected to the wall. As digital whiteboard hardware was not available, the teams also used Tele-Board at their laptops. Some teams only had one remote person, others had 3-5 people per location. The teams worked between Germany and India or Germany, Ireland, and Canada.

The design thinking project teams used Tele-Board for: storytelling from interviews, brainstorming, clustering interview or brainstorming notes, and presenting prototypes or ideas to each other. Teams used different ways of collaboration, depending on team structure and tasks. For brainstorming and clustering, the teams mainly worked synchronously and often for several hours.

> In this project we were 3 people in India and 4 in Germany and without Tele-Board it wouldn't have worked. This was the platform we used for exchange, for making things transparent. We also used the videocameras of the laptops, so that we could see each other, this was an extra medium that was nice to have a little more contact. Very important was: if we had written on an analog board, we had lost the people in India. In this way they could be present at the brainstorming, follow up on what we have written and vice versa. (DE3)

On the other hand, in a team with just one remote person, the core team worked with traditional tools in a design thinking room and just the remote person added her ideas via Tele-Board. For documentation, one team member often transferred the paper notes to Tele-Board. Team members who were ill or on vacation later used the panels to see what the team had done. Other teams decided to work in sub-teams at their locations, then meet for synchronization. Another team created a paper prototype at one location and uploaded a photo of it in Tele-Board. The remote colleagues then added their feedback in forms of scribbles and sticky notes on the photo. Other teams synthesized the interviews at their location and in a joint meeting each sub-team presented the interview results from their country.

The interviewees from China mainly used Tele-Board for collecting ideas and requirements for their current project. They collaborated with remote participants in other cities in China, Europe, or the US. Depending on the time difference, they worked synchronously or asynchronously. For example, when working with a consultant in the UK, the consultant prepared a panel beforehand, and in the meeting she explained the roles and tasks of the business process based on the sticky notes in the panel. The Chinese users, who were implementing the software, could ask questions during and after the meeting through sticky notes. One interviewee said they would also use Tele-Board if they were in one room because the session would already be in a digital format and documented (CN3).

The use of Tele-Board in the US was quite diverse. US1, located apart from the majority of his team, used Tele-Board frequently to present his ideas and findings to his colleagues:

> Many of my colleagues had never used it. It was more of a one-way dialog. I used it since I work remotely. I work in the US headquarters office on the east coast of the US. Because I have a global role, I work with colleagues in China, in Germany and in Palo Alto. So I shared my Tele-Board screen, collected feedback, organized, clustered concepts, and presented that information back to them. It was very good for me to organize my thoughts and to help me move forward with the strategy that I needed to put in place. (US1)

User US2, located in San Diego, and her project manager colleagues in Palo Alto and Portland mainly used Tele-Board for collecting topics and using them as a meeting

agenda in a conference call. She and another colleague saw Tele-Board also as a tool for scrum meetings and sprint planning in remote settings (US2, US5). At the time of the interviews, they were not involved in distributed scrum projects.

5.3.3.2 Advantages and Disadvantages of Tele-Board

Based on their workflow and tasks, the interviewees saw different advantages and disadvantages to Tele-Board. The evaluation also depended on whether users compared Tele-Board to other digital tools or to traditional whiteboards and sticky notes.

Comparison to Digital Tools

All interviewees said they saw Tele-Board's main purpose and advantage in collecting ideas, requirements, or feedback from people distributed over several locations. People highlighted that they could work together simultaneously (US2, CN1, CN2, CN3, DE3, DE4, DE5, DE20), which let them work faster in large meetings, even if they were at the same location (CN1, CN3).

> For example, when we collect the requirements, there are many people in the meeting, and if we make everyone to present their ideas one by one, it takes a long time, and if we use Tele-Board, in 5 minutes everybody can write down their ideas. Then all the team members can go through the ideas together and group them to some clusters. (CN3)

Tele-Board was also seen as a flexible tool for collecting ideas whenever you like (CN3, DE17), regardless of timezone. Before, people collected ideas via e-mail, where they easily got lost (DE17, CN5) or with MS Excel, which only gave one person the possibility to write at a time (DE2, DE4, US2).

> A lot of people can put in the stickies all at the same time. One person doesn't have to be that person who writes things and puts it in. Usually, if we have an Excel Spreadsheet or something like that, you can't have multiple people writing at the same time. (US2)

Several users found that meetings were more interactive if everybody had the possibility to contribute something at the same time (CN5, DE3, DE18, DE19, DE20).

> I think it has great advantages compared to Adobe Connect and audio only. With Adobe Connect, you just have a fixed Powerpoint or Excel that you rattle off and people are just looking. And they can't interact or you have to pass around the presenter rights. This is what I like with Tele-Board, that everybody who has an idea can just slap it out. (DE18)

> A clear advantage of Tele-Board is that it is substantially more interactive and that you can involve people. I also have the problem to see if people are still on board. I've already done WebEx sessions and how do you keep people with you? And this is given with Tele-Board, because it is more interactive, that's great. (DE19)

Giving all users the possibility to write something was also seen as an advantage because quiet people were more involved (DE20), people did not need to interrupt each other (DE5) and it was easier to understand different accents (DE19).

The possibility to rearrange and cluster ideas was not supported in other tools available to the interviewees (DE4, DE16, US1). The draft character of a whiteboard and sticky note application was also appreciated because it supported fast feedback loops (DE7, DE16).

> You have the possibility – which is obviously not the case with Excel and other applications – to capture things one after another and then move them around. That's great. In this way I thought it was a great help compared to everything I had before. It drove me crazy when people started with Powerpoint because they showed me something finished you cannot work with. (DE16)

> If you use Tele-Board you can say: have a look at it, it's still in progress, there are still open questions, I'm working on it. With a Powerpoint presentation I automatically have the aim: this must be finished if I send it around. And then it takes longer. (DE7)

When we asked the manager about his opinion after 1.5 years, he said that collaboration in the German-Indian-Italian team had developed further, trust among team members was high, and projects were successful. Furthermore, he thought communication across locations worked efficiently:

> I think that we are even more communicative and efficient, particularly cross-location, but also in a co-located meeting because we can work in parallel. Tele-Board has established itself for us. (DE8)

For his new team, he aimed for a similar increase in collaboration and communication. However, he thought this needed time because "a tool is always just a tool, processes and working modes have to evolve" (DE8).

A reason why people were not using Tele-Board, or thought others would be hesitant to do so, was the huge amount of tools already available. This made people reluctant to learn yet another tool (US1, US2, US5, DE4). Additionally, Tele-Board was not available to many in the company, so other tools everyone knew and had access to were often preferred (DE5, DE19, DE20). As Tele-Board was seen as "the design thinking tool" (CN2, CN4, CN5), some users said that they did not really need Tele-Board because there was no "design thinking workflow" in their projects (US3, US4), or they were not working remotely (US5). Especially the new users from China and the US were missing diagraming tools and shapes in Tele-Board for process modeling and architecture models (US1, US2, CN1, DE2). They pointed out that drawing or handwriting at a standard computer was cumbersome, and they would need functions to easily sketch or mock-up something. For easier collaboration, they desired an integration in the company's social network tool (US2), as well as a pointer and embedded video to increase awareness of remote participants (DE16).

Comparison to Analog Tools

The advantages and disadvantages described above relate to other digital tools within the company context. Since the introduction of design thinking to the company in 2011, more and more people were involved in different design thinking activities in traditional, co-located setups. With the advanced experience from the analog world, interviewees could now give more feedback on the comparison between Tele-Board and traditional whiteboards. This was especially true for interviewees with design thinking coaching experience (DE16, DE18, DE19, DE20), but also for users in the first study (DE1, DE3).

According to the interviewees, the main advantage of a whiteboard application was the digital format. This way, information could not get lost (DE1, DE20, CN2, CN4), it eased further processing (DE1, CN2, CN4), and a meeting room could be left directly, without collecting the working material (DE3, CN2). One user acknowledged the reduced waste of paper (CN5). Additionally, Tele-Board facilitated documentation because it was not necessary to take photos of whiteboards and decipher bad handwriting (DE3, DE19, DE20, CN2). If somebody was ill or on vacation, s/he could access the whiteboard history later (DE3, DE20).

People found that the biggest disadvantage of Tele-Board in this setup was the fixation to a laptop (DE1, DE7, DE16, DE19, CN2). The face-to-face communication was constrained and people easily got distracted.

> If you are sitting in a room with three people, and everybody looks on his screen and you are supposedly talking about the same thing, you have the feeling you are not talking about the same thing because everyone looks elsewhere. And also, if somebody starts to type like mad you ask yourself: what is he doing right there? Is he still with us? In this case, you have lost if you are the coach. You force them to bring their laptops and simultaneously you accept that they are distracted because they are reading an e-mail that just arrived. (DE16)

Furthermore, people appreciated the standing activity involved in work at actual whiteboards. A standard laptop forced them to sit again (DE1, DE3, DE16).

> This was a little disadvantage, that we were sitting to work with Tele-Board at a laptop. With design thinking, you usually actively jump through the room and this way it was not possible. I don't want to say it paralyzed, but this way you were in a sitting mode again. (DE3)

Especially when working for several hours, interviewees preferred the traditional way of working (DE16, DE18). Sitting in front of a laptop for a long time was considered tiring (DE3, DE18) and not as much fun (DE16). Additionally, sketching with a mouse was difficult (CN4, DE19), and many users would prefer to have digital whiteboard hardware (DE1, DE3, DE16, DE17, DE18, DE19, DE20, CN4). DE18, who had used Tele-Board with digital whiteboard hardware, confirmed that it improved the interaction. In the analog situation, nevertheless, the whiteboard was not located in a meeting room with audio conferencing equipment, and the team had to use mobile phones to communicate with remote parties. As the audio connection was not acceptable this way, they switched to a conference room without a whiteboard.

5.3.3.3 Introduction to Tele-Board and Ease of Learning

This section focuses on the fifteen new users of Tele-Board and how they learned the system without a formal training. The majority did not have any introduction and learned by doing (CN2, DE16, DE18, DE20, US1, US3). Others had an introduction from their manager (CN3, CN4, US4, US5) or their colleagues (CN5, DE17, US2). In these introductions, the most important functions of the whiteboard client and web portal were shown. User US1 read the help pages in the web portal, DE18 used a How-to-Slidedeck, created by IT1 from the first study. Some users wished for a 5 minute introductory screencast (CN4, CN3, US2) as they did not see the help pages (DE20) or did not consider them sufficient.

Several users found Tele-Board intuitive and easy to use (DE4, DE17, DE20, US1, US4, US5).

> To be quite frank, it was very easy to use. To be able to use the stickies, collect feedback, I think it was, in lieu of not having a whiteboard - just using it as a whiteboard was great. (US1)

However, there were also users who did not share this opinion.

> My colleague in the US for example, she did not think it was that intuitive, while others said it was great, super intuitive. It depends, I thought the handling was very easy. Sure, if I needed a special function like prioritizing with stars, that's a special question. But overall I thought it was easy and you could learn it in a playful way. But there are others who did not think it was that intuitive. Probably it depends on whether somebody has already worked with graphics tools, using the hand mode and selecting [..]. (DE17)

DE16 also said the first steps in the whiteboard client were easy to learn alone, but more advanced functions, like adding a picture from the web portal, needed more preparation.

> Honestly, I have to say, the biggest problem for me is: I use the software together with other people, now, ad-hoc. That means it has to fly directly, without thinking, it has to be intuitive [..] Because we do not have the time and the patience to attend a training, because we think, hey I know how to use sticky notes, it can't be that difficult. (DE16)

Most new users only used the main functions in the whiteboard client, sent sticky notes and images via the web portal, and exported a panel to Powerpoint. They did not use any of the sticky pad apps on mobile devices because the majority did not understand they were there.

5.3.4 Summary of Long-Term Study

Over the course of 1.5 years, the number of Tele-Board users and whiteboard activity increased. Through the members of the pilot team, more people got to know the system and established user accounts. In contrast to the study after three months,

there were now users with long-term experience with Tele-Board as well as new users with and without analog design thinking experience.

The users in the pilot team continued to use Tele-Board in a similar way as before. However, it was now customary to use Tele-Board "if you want to collect something". Even users who were rather doubtful about it before (DE2, DE5) acknowledged its use for distributed idea and feedback collections. Still, they and other users in the German pilot team said they did not have very many use cases for Tele-Board outside their global team meetings (DE1, DE7). In the server log data, we can still see a variance of activity between the German users. Compared to the Italian and Indian users, there is still less activity overall at the German headquarter (see Figure 5.8).

Several users with advanced experience in design thinking projects in co-located and distributed setups, complained about the constraints of a digital setup. Using a laptop forced them to sit and created a "barrier" in front of them. Additionally, laptops could distract from actual team work. Therefore, some users would rather work with traditional tools or with digital whiteboard hardware and mobile devices for creating sticky notes. Until now, these devices have not been available to most interviewees. Even when they were, they could not be used together with audio conferencing.

Although the way of working was different from analog setups, people appreciated that Tele-Board enabled them to work together in remote design thinking projects in a way that had not been possible before. Brainstorming together across different locations and structuring ideas in real-time was not supported by other tools, therefore all users appreciated these functions.

Another difficulty for several users was that they had to learn another tool in their tight schedules. Although most users confirmed that the basic functions were intuitive and easy to learn, not many users took the time to learn the more advanced functions from Tele-Board's help pages. However, some users did, because they likely saw the added benefit for their situation. "For me, because I'm almost exclusively remote, it's a great tool. Because it allows me to use stickies, organize, cluster and group stickies" (US1). The design thinking coaches DE19 and DE20 also learned more functions in order to teach design thinking methods worldwide and improve team work. They also created and promoted the use of templates in Tele-Board to ease the introduction of design thinking methods.

We also heard that remote design thinking projects before Tele-Board often did not take place because it did not work with the available tools (DE16, DE19, DE20). As a consequence, remote team members either had to fly to other locations for several weeks or not be involved, even if their expertise was valuable, or the team only developed prototypes presentable via desktop sharing (DE19, DE20). None of these implications were desirable, and several users were pleased that Tele-Board offered new ways of collaboration (DE3, DE18, DE19, DE20).

5.4 Recommendations for UCD Tools in Large Companies

From the analyses with different user groups on different experience levels, we gained insights into the advantages of using a digital whiteboard application in the mentioned company. The main goal was to find out which factors supported and which

factors hindered its adoption by employees worldwide. The following recommendations are based on the findings in this company. However they may be transferrable, as the general setup is similar to other global companies (Tang et al., 2011; Koehne et al., 2012; Huang et al., 2006).

Support standard computers as well, do not require installation

Overall, we found that it greatly helped that people could use Tele-Board on their standard computers. Users only needed log-in data to start the whiteboard application from their browsers. As we could see how much some users struggled to set the correct proxy settings, we can conclude that any installation process would have inhibited several users from trying out Tele-Board. Additionally, it was very important that users did not need any special hardware. During the 1.5 years, a digital whiteboard was acquired at headquarters, but it stood in a building and room not easily accessible by most users. Moving the whiteboard to another building required advanced logistics due to the size and weight of the board and has therefore not happened yet. But even if a few digital whiteboards were available, there was always need for easy and ad-hoc access to the whiteboard content. People needed the flexibility to use the application anywhere, in any meeting room or office. Furthermore, several employees frequently worked from home, especially when time zone differences forced them to have meetings outside of standard office hours. Any special hardware would have excluded these users.

Offer different hardware options depending on setup, task, and team size

From the interviewees, we learned that there were different ways to use Tele-Board, and depending on the respective situation and task, people had different needs and expectations. For an idea or feedback collection in a large team ($>$ 10 people) distributed over several locations, it worked fine for all users to type in ideas at their laptops because the goal was to collect the individual opinions of all team members.

However, project teams that usually work with traditional whiteboards and have come to appreciate design thinking working environments, are dissatisfied sitting in front of a laptop in a standard meeting room. For remote collaboration, comparable to co-located analog setups, the optimal environment in a company context would be the following: digital whiteboard hardware with finger and pen input, a video conferencing room with high tables and barstools, and a tablet or smartphone for each user to create sticky notes. With this setup, we are confident that remote design thinking work could be a lot more similar to analog ways of working (see also Chapter 4).

From the interviews, we learned the difficulty of setting up rooms like this on a worldwide scale. Even today, there are not enough video conferencing rooms available when needed and installing digital whiteboards in meeting rooms has not yet happened at any location in this company. Therefore a solution in a standard meeting room would be the following: connect one laptop to the projector in the meeting room and open the whiteboard client on this laptop. Use another laptop for a video conference with the remote location(s). All team members use smartphones or tablets for creating sticky notes. This way, all people in one room have one (projected) screen to look at and nobody uses his own laptop for tasks unrelated to

the meeting. Of course, seeing the remote team members on a small laptop screen is not ideal, and a video conferencing room is preferrable. However, even a small video gives some awareness of what is happening at the other location(s). Even in a normal meeting room, people could stand up and move close to the video camera to explain something or go to the laptop with the whiteboard client to structure the incoming sticky notes.

Due to the missing hardware for design thinking projects, teams could also work in sub-teams at each location, then meet only to present the work of the different sub-teams and give each other feedback. According to our interviewees, this worked well either by uploading photos of a prototype or presenting insights from interviews on digital sticky notes. Getting insights from other countries and learning from the sub team's way of working was seen as a great advantage (DE18, DE19). However, in some teams there was just one remote person working with a team of 3 or 4 people at another location. In these "hub-and-satellite" teams, remote team members are easily ignored and not really part of the team (Venolia et al., 2010). In these teams, Tele-Board could help to include the remote person, as DE3 said in Chapter 5.3.3.1.

In all of the described setups, Tele-Board can be used independent of its hardware. The ability to use a standard laptop lowers the entry barrier for first-time users. Once people are used to the software and other ways of working, they can foster the installation of more advanced hardware for an improved collaboration experience.

Support use cases with visible benefits compared to existing tools

Our original goal was to support user-centered design work in distributed setups. That is, working with user research data, ideating on future design solutions, and creating design concepts together. However, we found that Tele-Board was used in several different cases which are not necessarily part of a design process. For example, we saw that people created an agenda for an off-site meeting together or used it to organize the topics of a meeting. In general, many users noticed that Tele-Board made their remote meetings more interactive and encouraged all participants to contribute ideas or feedback. This could be achieved through the real-time synchronous editing other office tools did not offer. According to our interviewees, there were plenty of tools available, but none of them supported team-based idea or feedback collection and structuring. The whiteboard and sticky note metaphor has proven to be beneficial for many use cases because it gave a flexibility to arranging content that was also intuitive.

Besides synchronous collaboration, Tele-Board's asynchronous work functions were appreciated by several users. This way, they could prepare content at their convenience and present their work later in a meeting. Without switching the tool, people could transition between different ways of working (Tang et al., 2009). Especially for team members in different time zones, it was useful to work at the whiteboard on their own then meet for shorter consultation meetings. It was even possible that only one person in the team was an active Tele-Board user and arranged the content beforehand. In a meeting, others could then look at the content and share their thoughts verbally. Through this "live introduction" to the tool, they saw its capabilities and could then decide whether they needed it or not.

Start with basic functions, have advocates for advanced functions

The basic functions of Tele-Board – posting sticky notes and arranging them on the whiteboard surface – were the first functions that people learned or showed to new users. The majority of users learned to use the functions quickly. The more advanced functions (e.g. moving sticky notes from one panel to another or importing sticky notes from a text file), were only used by some people, usually when we introduced them. As with other tools, we should provide short introductory videos or tooltips to supplement the existing help pages. Whether they will be used or not is difficult to predict as interviewees confirmed that short how-to-slidedecks were not used very much. We think a promising way is having advocate users moderate meetings with new users and show more advanced functions and best practice workflows with the tool. The manager and other members of the pilot team (DE3, DE4, DE8, IN3) as well as some of the design thinking coaches (DE18, DE19, DE20) have introduced Tele-Board to several new users in this way.

Introduce methods, not only tools

From the coaches interviewed, we heard that the workflow in remote design thinking projects was different from projects at one location and the respective coach needed to adapt to this situation (DE19, DE20). Depending on team size and available equipment, the coach needed to introduce methods in different ways. The majority of users was also new to design thinking methods and had to learn a new tool *and* new workflows. In these situations, the templates created by more advanced users were very beneficial (DE1, DE19, CN3). We heard that people were also more comfortable using the tool when they were more experienced applying different methods in general. We think introductions to a tool should be connected to introductions to methods and best practices. If possible, team building activities from the analog world should be adapted to draw attention away from the tool and focus it on the collaboration itself.

5.5 Summary

Tools that support collaborative creative ways of working have not yet found their way into companies on a large scale. User-centered design activities are mostly done at traditional whiteboards with paper sticky notes, impeding direct collaboration with remote colleagues. The goal of this chapter was to show how a digital whiteboard and sticky note application was used in a company and which chances and obstacles it offered for its users.

Tele-Board was introduced in a company for distributed creative work and a study after 3 months of use with a focal point on one team, distributed over three locations was presented. Through server log data and interviews with almost all team members, it was possible to see how the system was used. Participants reported that synchronous and asynchronous idea and feedback collection could be done more efficiently with Tele-Board than with other tools. According to the manager, team collaboration improved, and the users at the subsidiaries of the company appreciated the new way of communicating across distances.

After 1.5 years Tele-Board was still in use and had eight times more (active) users than at end of the first study. Through additional analyses and interviews, we

found the pilot team was using Tele-Board as before, with even more activity in 2013. Several new users found Tele-Board's basic functions intuitive and easy to learn. In more advanced functions and different areas of application, we saw different behaviors and expectations. Some users wanted to use the system ad-hoc without any training, others took the time to read help pages or ask colleagues. In line with the experiences from the first study, we saw more willingness to become acquainted with the functional range of Tele-Board among those working remotely, away from the majority of their colleagues. These people liked to have a flexible environment for communicating informal thoughts and ideas across the distance. Whether this holds true on a general basis needs to be further investigated.

Besides the different advantages to Tele-Board's functional scope, we believe that the large increase in new users is due to Tele-Board's functionality on any computer without installation. Even at desktop computers, several users found a digital whiteboard and sticky note application very useful. However, over the course of the 1.5 years, more users wished for digital whiteboard hardware and to use Tele-Board in a setup that is more similar to analog ways of working. From what we have learned, a large scale distribution of big touch displays at multiple locations still lies ahead. Remote work with whiteboards – as in co-located setups – is therefore a future topic for large companies. However, with the prevalence of tablets, smartphones and other input devices, users will soon no longer be bound to laptops.

6. Extended Digital Support

The former chapter has shown that a great advantage of digital tools lies in the ability to collaborate over spatial and temporal distances. Besides other digital benefits like improved documentation or searchability, there are also tools that support particular activities in user-centered design processes (see Chapter 2.1.1). For example, several research projects focused on the *ideation* phase and fostering idea generation or "thinking outside the box" (e.g. Prante et al. (2002); Shih et al. (2009); Wang et al. (2010)). In contrast, for the *synthesis / consolidation* phase (Chapter 2.1.1.2) less research and tool support is available. This might be surprising, as it is an important phase in UCD processes because it determines how user research data influences the design solution. User research produces large amounts of data and the design team needs to consolidate the most important insights into a problem statement based on user needs. If this problem statement is properly framed, a subsequent design solution has considerably higher chances of acceptance from its users.

We observed how much design thinking teams struggle during synthesis and overall it is considered difficult to analyze qualitative data (Hinman, 2011; Kolko, 2011; Oehlberg et al., 2012). Therefore, it is important to improve the understanding of synthesis in general and explore opportunities for providing computational support.

After an overview of theoretical background and related work, I will present results from seven interviews with people of different levels of experience regarding information synthesis. Based on their needs, combined with findings from other research, I developed a tool to support the collaborative synthesis process for design teams. In this tool, each team member works with the data individually and applies tags to the research data. The tool then generates overviews that include the tagging results of all team members. Besides including the input of the whole team, it also guides users through the synthesis process. In a case study with six design teams, we studied how the tool supports teams compared to an unstructured synthesis condition. We found that the tool helped users to externalize their different points of view and that users perceived the synthesis as more balanced among team members. However, other users – mainly the more experienced ones – preferred the unstructured way because they could decide on their own how to arrange the information.

6.1 Understanding the Synthesis of Information in User-Centered Design Processes

Conducting in-depth user research is a vital part of user-centered design processes (Beyer and Holtzblatt, 1998; Goodman et al., 2012; Rogers et al., 2011). Finding out more about the interests of users and developing empathy for their needs helps to develop more useful and innovative products (Brown, 2009). However, in industry, clients might question the purpose of time-consuming and costly user research efforts (Kolko, 2011). This may be due to the missing visibility and tangibility of how this data is analyzed and integrated in the future design of a product or service (Kolko, 2011). In comparison, other parts of a design process are more easy to understand by non-designers as they can see what happens when the design team sketches new ideas or builds a prototype (Kolko, 2011).

Furthermore, user research usually produces large amounts of data, which is difficult to integrate into design ideas and solutions (Brown, 2009; Kolko, 2011). Paper-based affinity diagramming provides a tangible method of organizing observations and interview results according to semantic similarity (Beyer and Holtzblatt, 1998; Curtis et al., 1999; Harboe et al., 2012; Hinman, 2011). Usually, this is a team-based activity with the goal to "make sense out of the data" (Kolko, 2011; Oehlberg et al., 2012). While easy to say, it is very difficult to generate new insights and knowledge from the collected data (Hinman, 2011; Kolko, 2011; Oehlberg et al., 2012). It is particularly difficult to develop a *shared* understanding of user data among all team members, because each has a diverse perspective that guides his interpretations (Hey et al., 2007; Oehlberg and Roschuni, 2011).

Several prior research projects sought to transfer the process of synthesizing qualitative data with paper notes to the digital world (e.g. Harboe et al. (2012); Judge et al. (2008)). However, little research has focused on team-based interactions around qualitative user data. The goal of this research was to understand the challenges for design thinking teams to "make sense" out of their user research data and how they can be supported during this process.

6.1.1 Background and Related Work

The term *synthesis* is also used in other contexts, however what we call *information synthesis* is the practice of integrating, organizing, filtering and evaluating external information into the design process (Kolko, 2011). In other related work, this understanding of synthesis may be referred as *collaborative synthesis* (Robinson, 2008), *framing* (Hey et al., 2008, 2007; Schön, 1984), *sensemaking* (Naumer et al., 2008; Pirolli and Card, 2005), *collaborative sensemaking* (Novak, 2007; Umapathy, 2010), or *information analysis* (Isenberg et al., 2008).

Sensemaking describes the act of "making sense of user research information", although many interpret this term even broader as "the process of searching for and organizing information" (Russell et al., 1993). Many research projects focus on helping analysts make sense of large amounts of data in the internet (Qu and Furnas, 2005; Sharma, 2011), network analysis (Chau et al., 2011), or document analysis (Wright et al., 2006). This data often consists of "hard facts" that need to be combined, such as facts about digital cameras (Sharma, 2011; Shrinivasan and van Wijk,

2008) or neighborhood characteristics (Cheng and Gotz, 2009). In this understanding, the term also involves the seeking and searching for information (Pirolli and Card, 2005), not just the act of condensing information to create new knowledge.

This creation of new knowledge and insights from user research data can be cognitively demanding for design teams (Andre et al., 2014). Filtering, organizing and making sense of uncertain and ambiguous information is complicated and exhausting (Hey et al., 2008; Kolfschoten and Brazier, 2012). Team work supports the following steps in the design process, but it also introduces the difficulty of creating a common ground and making decisions all team members can support (Hey et al., 2007). Based on background and experience, people have different views on situations and interpret or frame them in different ways. People form individual *frames* that consist of implicit knowledge structures (Hey et al., 2007; Schön, 1984). Difficulties often arise when aligning individual frames to create a collective understanding (Hey et al., 2007). Especially when dealing with ambiguous information from user research, different individual frames lead to different interpretations. Therefore, it is particularly important that design teams combine their views for developing a single shared understanding. Dow et al. (2011) showed that sharing multiple design ideas helped to improve group understanding and increase group rapport. Sharing multiple designs helped people understand their partner's design rationale, leading to better results. Other researchers also showed that discussions play an important role and teams that synthesize their knowledge into a shared understanding tend to have more successful design processes and outcomes (Hey et al., 2008; Hill et al., 2002).

With regard to computational support, research projects on sensemaking have focused on searching for and navigating through huge amounts of data. They have developed tools for improving information visualization, searching, and tagging. They studied how different devices, such as large displays (Andrews et al., 2010), tabletop displays (Morris et al., 2010), or personal and shared devices (Wallace et al., 2013) can improve the sensemaking process. Novak (2007) and Umapathy (2010) also stress the importance of knowledge exchange in interdisciplinary teams and studied how teams come to a shared understanding during sensemaking. With his tool, Novak suggests that visualizing implicit knowledge structures improves the knowledge exchange among team members (Novak, 2007).

There are less tools that focus on the synthesis of qualitative user research data, that is, the "information synthesis" as we have defined it. This research often focuses on how to transfer paper notes to the digital world or augment them to make use of digital functions. For example, Judge et al. (2008) study how multiple display environments can improve affinity diagramming. Harboe et al. (2012) augment paper notes with barcodes for locating the notes via text search. Though these approaches improve the mechanics of creating affinity diagrams, they do not tackle the problem of supporting a team to condense and develop a shared understanding of information. A big challenge is the ambiguous nature of qualitative data in design tasks and the great amount of tacit knowledge that is important for the process. A system that addresses this topic is called *Dazzle* (Oehlberg et al., 2012). It allows design teams to share their collected files, annotate them, and capture whiteboard images. However, the sharing of information stays on the file level and does not support relating disparate pieces of information.

Andre et al. (2014) have addressed the synthesis of qualitative data with the help of crowdsourcing. In their studies, crowdworkers without domain knowledge were supposed to create meaningful categories from text datasets. They found that seeing several data items and labeling them produced better categories than grouping the items and then labeling the groups. Although the authors have shown that a synthesis can also be done by crowdsourcing, we want to focus on supporting the design team itself. Dealing with user data is important for designers as it helps to better understand the problem they are trying to solve (Kolko, 2011) so they can create a design solution.

To broaden our own understanding and experience of the general needs of users and to relate it to the findings of other researchers, we interviewed designers with different levels of experience on how they manage the information overload and how they synthesize their insights with a team.

6.1.2 Interviews on Information Synthesis

We conducted seven interviews with two design students, four professional designers (graphics and interaction designers), and one design professor. The interview length varied between 20 and 45 minutes. We used interview guidelines focusing on how people condense, select, and decide when synthesizing information and how they evaluate the approaches they employ. All interviews were taped with a voice recorder. We used open-coding techniques to discover patterns and recurring topics (Corbin and Strauss, 1990). For each interview, we wrote various memos on sticky notes, clustered them on separate boards, and analyzed similarities and differences between the interviews afterwards. The main topics we identified in the analysis are described here briefly:

A Crucial Point for the Entire Design Process

Mainly the expert designers assimilated information "on the fly" and most of the time on their own. In contrast, other interviewees stated that the synthesis was a very crucial point within the whole design process, and its importance should not be underestimated, as it helps in identifying general statements, principles, trends, needs, and requirements with regards to the design task.

> I think it is the fundament for everything that follows [..]. I think that it is important that the whole group has a shared language and a shared collection of insights.

No Standardization around Organizing Data

Most people start by communicating their user research results to other people, either to one colleague or a whole team, depending on company or school structure. During these conversations, people usually take notes, either on normal paper or sticky notes. Some participants summed it up under the term "storytelling." Afterwards, they try to find similarities in what they have heard and try to group them by general terms ("clustering"). Important topics are sometimes displayed in different frameworks or diagrams, such as a process diagram to show workflows or relationships. In the end, people write down their most important insights or

principles. This relates to Kolko's methods of synthesis as e.g. "prioritizing" or "concept-mapping" (Kolko, 2011) or the observations of other researchers (Hinman, 2011; Robinson, 2008). However, not all follow an elaborated structure when synthesizing information; they pursue a rather intuitive, coincidental sequence of steps.

Synthesis Decisions Guided by Intuition

Decision making occurs when designers must prioritize or select between different pathways. We learned that intuition plays an important role for decision making in information synthesis. When we asked our interview partners how they identify and define insights or decide on their priority, none could give a clear answer. In particular, experienced interviewees said they follow their intuition and state that especially the increasing experience of designers enables good intuitive decision making. Interviewees with little experience stated that decision making is important but very difficult due to their lack of decision-making experience.

> That's the way it is: a team decision making process that is super difficult. Super dry, long, and exhausting.

> I think it is just experience; that you have the feeling, these are insights I can work with.

Literature also suggests that the role of intuition is supported by experience (Beyer and Holtzblatt, 1998; Cropley, 2006; Kolko, 2011). Accordingly, experience helps to develop tacit knowledge about different situations and implications.

Amount of Discussions Varies Among Teams

Our interviews suggest that discourse between the members of a design team is seen as a decisive part of information synthesis. An interviewee even defined the synthesis as "a team process with a lot of discussions". On the contrary, other interviewees stated that they collect and synthesize information generally on their own and talked later on about their observations only with a few people, generally expert designers. Thus, we could observe that the amount of discussions varies with teams and design situations. Research shows that discourse among design teams is rather important for user-centered design (Hill et al., 2002; Krippendorff, 2006; Lloyd, 2000).

Analog Forms of Media Predominate

Our interview partners use different kinds of media to communicate and process information, though analog media such as paper, sticky notes and traditional whiteboards are the most commonly used. Nevertheless, especially interviewees working in companies (instead of education) stated that at some point digital media in the form of word processors, presentation programs, or wikis are used as well. This is the case when they must share their findings with colleagues or other stakeholders outside the team.

Extent of Convergence Depends on Experience

Converging information and finding design principles with a higher degree of abstraction is one of the goals of the synthesis phase. However, we observed different levels of information trade-off among our interview partners. Some interviewees try to keep and externalize as much information as possible, partly because they are afraid to lose information and partly because their stakeholders set these restrictions. Others stated that it is not possible and also not desirable to keep all information in the design process, as it is important to quickly focus on the most important points. Most interviewees agreed it depends on the level of experience to decide which and how much information is important to process in the design process.

Team Dynamics & Dominant People Strongly Influence

We observed several incidences through the interviews in which implicit team dynamics influences the synthesis process rather unconsciously. For instance, interviewees mutually agreed that only if team members share a common ground of trust and respect, can there be a basis for joint decisions (cf. Schumann et al. (2012)). In another example, an interviewee stated that those who better enforce their own view strongly influence the whole synthesis process.

> It's a critical phase in the team process because dominant people often prevail and then their user research data prevails, too. It is important that all information is worth the same.

Also, the synthesis is described as exhausting and its success highly depends on team member's motivation. Therefore, we regard team interaction with a special focus on team dynamics, biases and motivation as important for a deeper understanding of information synthesis.

Teams Struggle to Communicate Synthesis Results

Interviewees who are working in companies stated that customers and stakeholders complain that they hardly see what happens during the synthesis phase (cf. Kolko (2011)). Several clients want to understand where the design ideas and solutions originate and whether the budget for e.g. user research was spent reasonably. However, such requirements generally presume seeing the relationship between design solutions and user research data, which is normally only possible towards the end of the design process. Particularly in the early stages of the design process, designers often struggle to communicate the design process' progress. In this context, information synthesis can help to create presentable states of knowledge. However, our interviews suggest that this seems to be less of a problem for the more experienced designers, as the relationship between clients and designers builds upon trust. This shows that external communication requirements depend on the relationship between designers and clients and how much they confide the respective design approach.

Organizational Circumstances May Hinder the Process

A challenge is little time for synthesis in general and many disruptions, especially in companies where people are working on several projects at the same time. In

this case, teams also face the problem that one or more team members are missing, making it difficult for them to catch up afterwards. Sometimes there are strict rules on how the synthesis should be done. On the other hand, research goals often are not clearly defined and lead to problems between the designers and clients.

Summing up, we draw the following conclusions from the interviews and our own experience on information synthesis: The synthesis is important and necessary while being difficult and exhausting, or – as one of our interviewees said – "The synthesis is a necessary evil". Mostly it is a stressful team process depending on strong team dynamics. Especially for beginners, it is challenging because it heavily depends on experience and intuition. Much uncertainty and ambiguity is involved, making the whole process neither visible nor tangible for outside observers. Last, but not least, it takes a lot of time, which is often not provided or scheduled.

For a more detailed analysis of the interviews and a framework we derived from them, as well as a literature review related to design research, see Gumienny et al. (2011).

6.2 Support for Collaborative Synthesis

Combining the insights from interviews and related work, we sought to improve different aspects that seem to influence the process and outcome of the synthesis. First, we want to help team members have a better understanding of the information they collected during user research. Each team member shall have time to familiarize and engage with the data collected, especially with the notes written by other people. Therefore, we want to give each team member some time to work with the data individually in the beginning of the synthesis.

Second, we want to support teams in forming a *shared* understanding. We think that visualizing these personal views of each team member is an important prerequisite for providing insight into community perspectives (cf. Novak (2007)). We want to create explicit representations of knowledge structures (Umapathy, 2010) and let the team compare and analyze different representations. If the team is unaware of these differences before a decision, this may result in conflicts that hinder the ongoing progress and it is important to understand each other's perspectives (Hey et al., 2008).

Third, as stated above, we heard that in some teams, rather dominant team members lead the whole synthesis and decision making process. As a result the outcome does not necessarily reflect the opinion of the whole team, possibly leading to later conflicts and disregarding the advantages of multidisciplinary team work. Therefore, we want to assure all team members are involved equally and show the contribution of each person.

Fourth, we want to give novice designers more guidance and encourage them to work with the data. They should have support in getting started instead of discussing how to deal with the huge amount of sticky notes as we have often observed in student teams. People told us that they perceive the whole process as very exhausting. We hope that it feels less stressful and more managable if we divide the synthesis into different steps designers may follow one after another.

6.2.1 Synthesis Guide

Combining these topics, we created a Synthesis Guide for a digital whiteboard system, which provides guidance and lets people work individually first and externalizes the team members' points of view in the end.

The main instrument of the Synthesis Guide is the act of applying different "perspectives" or "tags" to the user research data. The process of applying the tags is similar to the worker tasks of the Cascade system by Chilton et al. (Chilton et al., 2013). In this system, crowdworkers generate tag categories for a set of items. The best tags are picked, then they are given to other workers who apply the tags to the items. This crowdsourcing approach could also be used for user data here. However, we think it is important that the members of the design team do these tasks because they also carry implicit knowledge from user research. Additionally, they should use the knowledge they generate during synthesis for idea generation and prototyping later on.

We see a "perspective" or "tag" as a frame or point of view that can be applied to situations or data (Kolko, 2011). This is based on the assumption that different people generally have different mental models (Klimoski and Mohammed, 1994; Lim and Klein, 2006). These mental models are based on what we have learned and experienced, and we see the world from this perspective (Hey et al., 2007; Kolko, 2011). With the task of applying perspectives to pieces of information, the different perspectives of team members are externalized and shall make them aware of the different views they have (especially in interdisciplinary design teams (Brown, 2009)). During discussions, we noticed that the term "perspective" is not understood immediately and instead of "applying perspectives", people preferred the term "tagging". Therefore, we continued to use "tags" instead of "perspectives".

In the first step of the Synthesis Guide, each team member shall get an overview of all sticky notes written by the team after conducting user research. In order to reduce the overload of seeing all sticky notes at once, the notes are presented in groups of three on each page. With the help of the "next" button, users may flip through all notes, see Figure 6.1, top.

In the second step, each user is to create a perspective or tag related to the sticky notes they have seen, Figure 6.1, middle. Alternatively, they may choose one of the example tags offered. Each user creates his own tag that he or she considers interesting. To avoid duplicates and foster a broader range of tags, users will see tags already created by their team members.

After all team members enter one perspective, the Synthesis Guide will lead to the third step, the tagging view, see Figure 6.1, bottom. Each sticky note will be displayed on one page together with all tags the team has chosen. Additionally, the tag "important" is offered to indicate that a note is important even though it does not fit to any of the chosen tags. Users shall now select all tags that fit to the displayed sticky note. They can select as many tags as they like, or none at all. After pressing the "next" button, the tags are saved and the next sticky note is displayed. Each team member should do the tagging individually. By going through the steps of the Synthesis Guide everybody is "forced" to engage with the data and cannot leave this to other team members. Additionally, the point of view of each member is collected.

Figure 6.1: The three steps of the Synthesis Guide. First, each user shall read all sticky notes. Second, each user creates a tag that should be applied to the sticky notes. Third, each user tags every sticky note with the tags of the team. The important tag is provided by the system for highlighting notes that should get special attention afterwards.

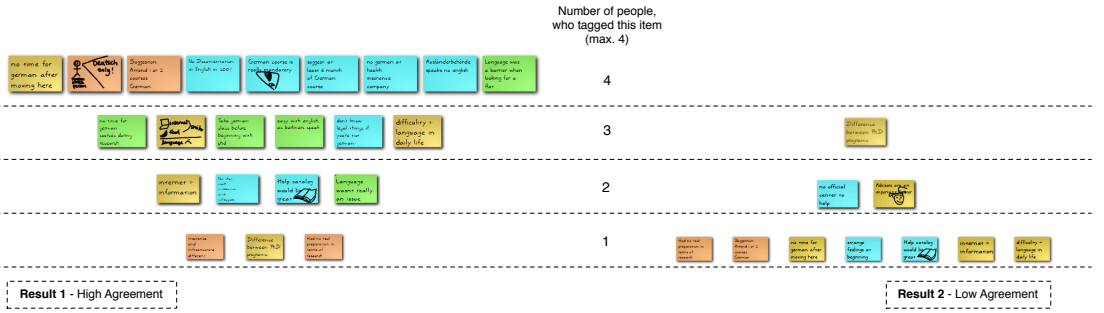

Figure 6.2: Examples of the result screens after the tagging. On the left, the team has a very similar understanding with regard to this tag ("communication barrier"), because several sticky notes have been tagged by all team members. On the right, the understanding is pretty diverse, as the majority of notes has only been tagged by one person (with the tag "important").

After each team member has completed the three steps, the system offers a result view for each tag, see Figure 6.2. Sticky notes selected by all team members appear on the highest level and are enlarged. Depending on the number of selections, the other notes are displayed on a lower level and smaller. Sticky notes not selected at all are not displayed. The result pages shall give an overview of how the team understands the collected information. For example, in Figure 6.2 right, the team obviously had different opinions on which sticky notes, i.e. what information on them, are important. The team can now discuss why they think certain information is important or not. On the other hand, they share the same view on "communication barriers", Figure 6.2, left. This may strengthen the team spirit and sense of community.

6.2.2 Design Objectives

The system embodied the following design objectives:

View Data From Different Angles When people apply different tags to the sticky notes, they think about the relationship of the respective tag with the data set. This way, they must see the data from another angle or frame. While people contemplate the data and try to view it from new angles, they engage with the data in a way they would not during standard clustering. This in-depth engagement with the data may lead to a better understanding.

Externalize Different Points of View When people apply tags individually, they do it without being influenced by their co-workers. On the results pages of the Synthesis Guide, the different opinions are visualized. We assume that people are often not aware of their different points of view, and in the results pages of the Synthesis Guide, the team sees the similarities and differences of views from the different tags. Based on these views they can start a discussion and come to one shared point of view.

Involve All Team Members Equally When each team member is tagging the notes, they are forced to engage with the data and cannot leave it to their fellow team members. The input of all team members is also counted equally and displayed on the results pages. This way, no team member is shut out, and everybody is involved equally.

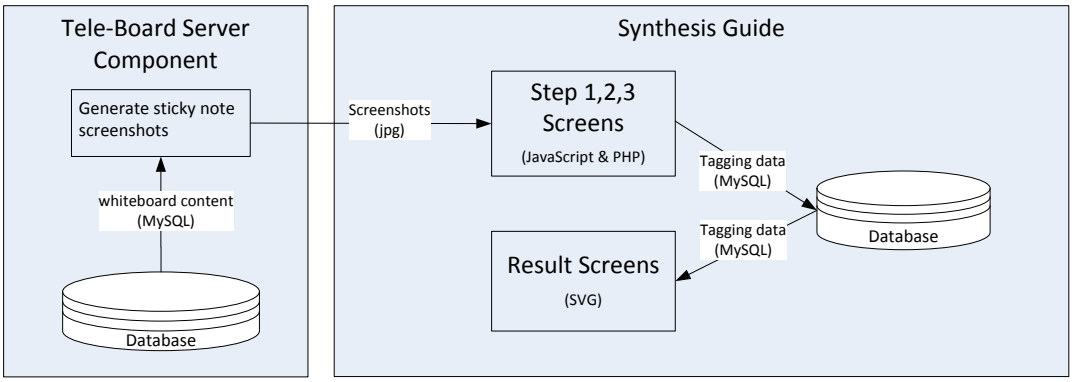

Figure 6.3: Synthesis Guide infrastructure and interplay with existing Tele-Board data

Give Guidance for Novice Designers Through its predefined steps, the Synthesis Guide shall give guidance to the team and help them get started with the synthesis. We observed that especially novice design teams often do not know how to start and waste time trying to agree on a method or framework to use for the synthesis.

6.2.3 Implementation Details

The Synthesis Guide is a web-based application so that it may provide easy access from the browser. The three different steps are implemented using server-side PHP scripts and client-side Javascript to enable interactivity within the browser (e.g. selecting the tags). In Step 1 and Step 3, the sticky notes are generated out of existing panel data from the Tele-Board database, see Figure 6.3. Thereby, the Synthesis Guide can work on every whiteboard panel that can be configured. The sticky note image generation is part of the Tele-Board server component.

The tag/user/panel relationship is stored using a MySQL database. From this data, the result views are generated fully automatically. On the resulting view pages, SVG is used for displaying the sticky notes. For the study, drag and edit functionality of the sticky notes was deactivated to provide a read-only view of the results.

6.3 Evaluation

To evaluate whether the Synthesis Guide really improves the synthesis and helps a team come to a shared understanding, we conducted a case study. We ran a series of pilot studies, then created a within-subjects study with two conditions, see Figure 6.4. We tested the Synthesis Guide condition, i.e. a structured way of doing the synthesis, compared to an unstructured clustering condition to find out which effect the structure and the tagging functionality have for the team process during synthesis.

6.3.1 Participants

We recruited 24 participants into six teams. Three out of the six teams started with the structured condition, three with the unstructured clustering condition. All participants had previous experience with design thinking and synthesis, but

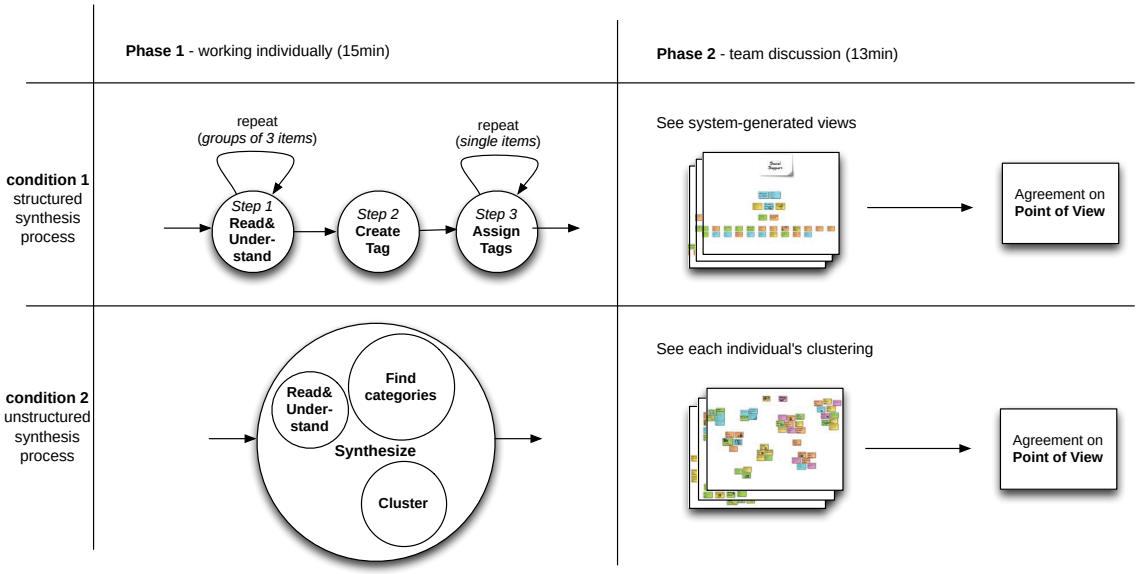

Figure 6.4: Study setup for evaluating the difference between a structured synthesis process with the help of a Synthesis Guide and the unstructured clustering where each user could arrange the sticky notes freely. In both conditions, the team members were working on their own in the first phase. Afterwards, they created a point of view of the given data in a team discussion.

on different levels. All teams were interdisciplinary, i.e. participants had different academic backgrounds, and consisted of four people each. Of the 24 participants, 14 were female, and all teams were mixed-gender. The average age was 28 years. Most participants did not previously know each other.

6.3.2 Procedure

In both conditions, the teams received a dataset of sticky notes and were to create a point of view (POV), a sentence that summarizes the most important findings from the sticky notes. In a real situation, these notes are written by the team members themselves. Due to time constraints, we offered notes created by other design thinking teams after interviewing people about two challenges. These challenges were: "How to improve the arriving experience of foreign researchers coming to a foreign university" and "How to improve the airport check-in and boarding process". The datasets consisted of 50 sticky notes each. Each challenge was done three times with the structured condition and three times with the unstructured clustering condition.

In the structured condition, teams used the Synthesis Guide. First, each team member read all sticky notes on a laptop by clicking through the pages of step 1. Then, each person created one tag or perspective. As a last step, they tagged all notes with the tags they created. The teams had 15 minutes to complete the steps of the Synthesis Guide. Afterwards, they looked at the results pages and had 13 minutes to discuss these results and create a team POV from the data (see Figure 6.4).

In the unstructured clustering condition, each team member had the sticky note dataset in a digital whiteboard application on a laptop. The sticky notes were grouped by color (based on the interview person), see Figure 6.5. People could

Figure 6.5: Start screen for the unstructured clustering condition. The sticky notes were grouped by color, representing the different interview partners. Participants could rearrange the sticky notes freely and create their own structures of the notes.

move around the sticky notes with their mouse and cluster the notes as they liked. Additionally, they could zoom in and out. All other functions of the whiteboard application were turned off to make people focus on the content instead of the functions. Each team member had his own laptop and 15 minutes to work with the data individually. We gave the instruction: "get an understanding of the information on the sticky notes". Afterwards, the team sat together and had 13 minutes to discuss what they learned from the data and to create a team POV as in the structured condition.

In the first phase of both conditions, when the teams worked individually at their laptops, they were sitting around a table and could not see their fellow team members' screens. In the second phase, when discussing their findings and creating the POV together, we had them now turn around the laptops and place them in one row. This way, everybody could see all screens at the same time and they could point at sticky notes on the screens, see Figure 6.6.

After each condition, the team members separately filled in three forms: one with his or her most important insights from the data, one with comprehension questions related to the respective challenge, and a post-task questionnaire. After conducting both conditions, each participant additionally filled in a post-test questionnaire. The post-test questionnaire included Likert-Scale questions as well as free response questions. Each experiment lasted about two hours.

6.3.3 Quantitative Results

In the post-task questionnaire, different questions asked about similar understanding among team members, how easy it was to understand the team member's points

Figure 6.6: In both conditions, the teams first had a phase of working individually (left). Afterwards, the laptops were put in one row in order to see the clusterings of each participant in the individual condition or the tagging result views in the wizard condition (right).

of view, the participants' satisfaction with their own contributions and with those of their team members, time management, whether they felt they were on the right track, and the general difficulty creating the POV (see Appendix C for the questionnaires). We performed an analysis of variances (ANOVA) with the condition (structured or unstructured clustering) as a factor and the responses to the Likert-scale questions as dependent variables. Between conditions, there were no significant differences for all questions, see Appendix C.

In the post-test questionnaire, we asked in which condition the common ground or understanding was best. We saw a marginally higher value for the structured, Synthesis Guide condition (on average 1.46, SD=0.51 opposed to 1.54, SD=0.51 in the unstructured clustering condition, values ranging between 1, best and 2, worst). We also asked for factors like efficiency and fun. The mean values hardly differed: 1.54, SD=0.51 (unstructured clustering); 1.46, SD=0.51 (structured clustering) and 1.42, SD=0.5 (unstructured clustering); 1.58, SD=0.5 (structured clustering).

Additionally, we analyzed the insights questionnaires regarding general quality and similarity among team members. For both attributes, we could not find differences between the conditions. Some teams in general had more similar insights than other teams, but not between the conditions.

To test a team's comprehension of the given data, we created five sample questions for each data set. Each correct answer received one point, and we calculated the amount of points a team earned per condition. We could see slightly better results for the unstructured clustering condition with the foreign researchers challenge (on average 12.67 points opposed to 11.00 points in the structured clustering condition), but these values are not significant. For the airport challenge there was no difference: on average 17.00 points in the unstructured clustering condition, 17.33 points in the structured clustering condition.

For all of the reported measures, we could not find significant differences between the conditions. Therefore, we focused our analysis more on qualitative data, that is, the free response questions of the post-test questionnaire.

6.3.4 Qualitative Results

Overall, we observed that all teams in all conditions created POVs within the given time frame. All team members participated, though some were more active than others. In the Synthesis Guide condition, each team created a perspective as directed. Some participants did this very quickly; others needed some time. Some teams asked each other clarifying questions about the perspectives, especially to dissociate them towards each other.

In the post-test questionnaire, we asked which condition the participants preferred and for what reasons. We also asked which advantages and disadvantages they saw for each of the conditions. The results are summarized with regard to the main findings.

Showing All User Data Supports Overall Comprehension

For overall comprehension, people preferred the unstructured clustering condition. They liked the ability to structure the sticky notes on their own in as many clusters and hierarchies as they needed:

> It has the advantage that everyone can use as many clusters as he likes for his own sensemaking and not just 4/5 tags. (T4P1)

Participants also pointed out that they liked having an overview of the information on all sticky notes at a glance and have it always visible:

> It is an advantage to arrange post-its directly on the screen while having all the post-its in an overview and on the same screen. (T6P3)
>
> During clustering you see groups emerging, and in the end you try to find a name. When you have to tag notes before, you kind of have to know the names first. (T3P1)

In the structured condition, some participants were afraid of forgetting or losing important information. The reasons may be the following:

> The facts people vote for most don't have to be the best or most important ones (T5P4). It implies that the insights that can't be categorized so well are not so good, which isn't true. (T5P2)

In summary, having an overview of all sticky notes and being able to structure them helps people to get a better understanding of the data. In their comments, people did not point out that the tagging had an influence on seeing the data from another angle, as we had anticipated. The tags were rather seen as fixed categories equivalent to cluster names. In this sense, people found it problematic to define the tags before they had worked with the data.

Both Ways Can Help Form a Shared Understanding

The comments regarding shared understanding are divided. Some participants said the tagging result views helped them find a common ground faster because they had the overviews and needed less discussions:

> I think it can demonstrate common ground very easily and doesn't lead to so much discussion about which post-it should go where. (T4P1)
>
> You see the most tagged post-its. This way you get a quick overview and a faster common ground with the team members. (T4P3)

Others saw advantages in using the Synthesis Guide but did not really know why:

> Maybe it was just the example, but the clustering felt quite natural. We had the most important facts immediately. (T2P4)
>
> In the end it seemed to be more clear, what the interviewees said and how the others think about it. (T2P3)

Two participants also acknowledged the "important" category because sticky notes can be highlighted without a special reason:

> Especially the important tag is interesting. Cos you sometimes have a feeling this is important, but don't know why. (T5P1)

However, six participants had problems with creating the tags and misunderstandings with them. They disliked being limited to four and that they could not change them afterwards. Although they were able to ask their team members questions about the tags, they saw problems in interpreting them: "There was some confusion about the tag-categories" (T5P4), and this user feared it was "just the least common denominator". Other participants generally saw more advantages in the unstructured clustering condition. They felt that the information sharing and discussions were more vivid and personal. "It was much more organic and invites to dialog" (T5P2). Or overall:

> It felt that the team reached a better common understanding of the challenge even though we didn't talk about it like with the [system], but the building of clusters seemed to give us better tools to share our understanding (T4P1).

In summary, we cannot say that the tagging generally helps to come to a shared understanding. For some teams it did, but for other teams clustering the sticky notes was more useful.

Participants thought Structured Synthesis was more Balanced

Several people pointed out that the Synthesis Guide showed the overall team opinion and involved everybody:

> The [system] makes it pretty clear what is the team's opinion is, also from the people which where not so "loud" and gives a good overview. (T2P2)
>
> More fair, everyone's opinion counts. (T5P1)
>
> Balances team members dominant vs. introverts as you mostly consider what you ALL agreed on. (T6P3)

Furthermore, they liked that people were not influenced by each other:

> People are not that much influenced by others, because the rating was done secretly. (T1P2)

In the unstructured clustering condition they thought it was interesting to see the different clusterings from their team members and compare them to their own clusters:

> First you can cluster it your way and then see what the other team members came up with. (T4P3)
>
> You can cluster and think first on your own and create a picture in your mind, so you can discuss with the team better, because you already thought about it, and talk only about essences. (T4P4)
>
> You can really see how people work and how they organize their findings. (T2P4)

On the other hand, two people saw the danger that it was easier for a dominant person to take the lead:

> A dominant person can push her view on the topic harder, when explaining her way of clustering. (T6P3)
>
> It is easy for somebody to get in control of the process alone. (T2P2)

The Synthesis Guide Provides Guidance for New Users

The participants of the study had different levels of experience. In their comments after the test, people who had just finished design school pointed out that the Synthesis Guide was helpful. In the free-form responses, participants also commented that they liked the guidance of the tool: "With a program like this, it's more structured and always clear what to do" (T4P3). Several participants perceived the process as easier and more structured: "It is easier to concentrate on the single post-its" (T6P4). "You are not overwhelmed" (T3P2). "The use of a proper interface to choose among the topics made it easier to visualize it" (T3P1).

6.3.4.1 General Preferences

In the post-test questionnaire, we asked the participants about their general preference, i.e. which way of doing the synthesis they preferred. From 24 participants, 12 participants chose the structured Synthesis Guide condition and 12 participants the unstructured clustering condition. These divided opinions can also be seen in the overall comments of users:

> So all in all the [system] saves you a lot of clustering and cluster-discussion time that you can spend later to create a better PoV. For me, the [system] makes the process more based on individual ratio and choice which I like a lot. (T2P3)
>
> The "tagging" method is efficient but makes synthesis very scientific. There could be a danger that people just go for insights that were very clear to categorize. (T3P4)
>
> There was a lot of guidance, but also the feeling that one looses information, e.g. if a category is missing. (T2P2)
>
> I don't like the tagging, I like to see my clusters and to think while shifting the post-its around. (T4P4)

Summing up, some people preferred the new guidance and tagging result views of the Synthesis Guide because it created an equally balanced process involving all team members and helped in coming to a shared common ground. Other participants preferred the unstructured clustering condition because they could freely cluster the sticky notes as they liked and thereby get a better overview and common understanding with their team members.

6.3.4.2 Experts Evaluation

We also gave the POVs that the teams have created to design thinking experts (with coaching experience) to let them evaluate the POVs according to three characteristics (insightful, actionable and overall) on 5-point Likert-scale questions. Additionally, the experts had to choose the best POV per team. Ten experts rated the twelve POVs that were created by the six teams. For analyzing the evaluation of the characteristics, we performed an analysis of variance with repeated measures with condition as a factor with 6 levels (for the 6 teams). We could not find significant differences between the two conditions. When choosing the best POV per team, in three cases, the experts preferred the POV of the Synthesis Guide condition, one time the POV of the unstructured condition, and two times the result was undecided. On average, the structured condition got a score of 5.5 (SD=2.07), the unstructured clustering 4.5 (SD=2.07).

6.3.5 Limitations

To identify statistical differences between these approaches, we would need more participants. It would also be interesting to test with design thinking novices only, considering they need the most support during synthesis as we have identified in the interviews. Additionally, it would have been good to have teams that already know each other at least a bit. Both of these requisites were true for some participants and teams, but not for all as the scheduling of the studies did not allow this.

6.3.6 Summary of Case Study

Several users confirmed that the individual tagging helped to equally involve all team members into the process and see the different points of view. However, seeing different clusterings of each team member also gave insights into the views of the others. Regarding a shared understanding or common ground, participants were

divided into two groups: some said the clustering better supported discussions and coming to one shared view. Others preferred the tagging result views as the basis for discussions. Several participants liked the different steps of the Synthesis Guide, saying it helped in the beginning, made the process easier and let people feel less overwhelmed.

In summary, there is probably not one way that helps *all* design thinking teams during information synthesis. However, as depicted in the interviews section: there are a lot of different needs and preferences based on the experience of people involved. For design thinking novices and teams that do not know each other very well, the Synthesis Guide and its tagging functionality seem to be good for the beginning of the synthesis. This way, they can get an idea of the opinion of others and make sure everyone is involved. In a second step, the tagging results views can be the basis for clustering as people are used to. For experienced and well-working teams, the Synthesis Guide is probably not necessary because they know how to proceed and work with each other.

Regarding the tagging functionality, people should be allowed to create more tags and maybe the system should introduce more "meta tags" such as Important, Surprising, or MyFavorite, to let people highlight more "fuzzy" sticky notes. However, we still want to emphasize the notion of a "perspective" that should force people to see the information from a different angle. The tags were mostly interpreted as fixed cluster categories and therefore often seen as too rigid for the process. Our intention was to apply perspectives for intentionally changing the angle of view on the data. If every team member proposes one of these angles, people are forced to think in a way they may not have thought before. In the future, we have to consider how to convey this meaning of tags or perspectives (and which word to choose) and how to test their influence in this intangible phase of the design process.

6.4 Summary

In this chapter, we analyzed the difficulties of synthesizing user research data in order to make sense of it as a team. Through interviews, we found that it is perceived as a stressful team process that is especially difficult for novices because it depends on experience and intuition. Furthermore, it is an ambiguous, nontransparent process that takes a lot of time.

Based on these findings, we wanted to create a tool that has the following features: helps in getting a better understanding of the user research data, provides a more balanced team process where everybody is equally involved, helps to come to a shared understanding more easily, and guides through the process and helps in "getting started". We presented a Synthesis Guide to achieve these objectives with a phase of working alone as well as the option to apply "perspectives" or "tags" to the collected sticky notes.

In a case study, we tested this structured way of doing the synthesis compared to an unstructured clustering condition. There were no significant differences between the conditions from questionnaire data. Therefore, we drew our conclusions from the subjective free form text answers of the 24 participants. We learned that participants really appreciated an individual working phase before entering a group synthesis phase. Novice designers tended to prefer the structured computer-supported

synthesis process that externalizes the different views of each team member, while more experienced designers preferred to freely arrange information segments and create clusterings on their own.

Based on the case study findings, we suggest that teams generally include a phase of engaging individually with the data in the beginning of the synthesis, even without tool support. Each team member may also note down how to structure the data and then the team shares the different views. Tool support would have the additional benefit that team members could individually prepare location and time-independently. With the Synthesis Guide, they could use smartphones or tablets and tag the notes from user research already on their way to work. Thereby, everybody would be acquainted with the notes written by their colleagues before a synthesis meeting and the team could save time overall.

This chapter has shown that the synthesis phase of a design process is complex, and there is no straightforward way of doing it. One tool that offers synthesis support was proposed, but certainly there are other ways to help designers consolidate their user data or motivate the team. This research has focused on team dynamics and shared understanding among team members. Other research could investigate if it is possible to consolidate the data automatically and if this is adopted by the design team. Research projects could alternatively focus on visualizing the process, in order to give the team and other stakeholders an overview of the flow of information and evaluate whether all user data is included. Overall, there are many areas to further explore; this research aimed to be a starting point.

7. Evaluation of Studies

The last three chapters have shown how Tele-Board and the Synthesis Guide have been used in different contexts. In the first study, the goal was to investigate how well Tele-Board supports design thinking in a co-located setup. All teams could complete the given tasks in a similar way as they were used to. However, the digital whiteboard decreased the user experience and the opinions of the participants were generally divided on a digital system for design thinking. Still, consensus was that the greatest value of Tele-Boards resides in the opportunity to work remotely. In the second study, the adoption of Tele-Board in a large company was investigated through field research. With the help of interviews and usage statistics, we saw that Tele-Board was adopted by a large number of users and improved remote collaboration. In the third study, we investigated how a Synthesis Guide could support information synthesis. We learned that a more structured procedure especially helped novice designers, whereas experienced designers preferred to have more flexibility.

7.1 Common Insights

Besides the study-specific research questions, the underlying question in all studies was: when do people use a digital whiteboard system and when do they not? In each chapter, the advantages and disadvantages of Tele-Board or the Synthesis Guide were compared to the advantages and disadvantages of other digital tools or traditional working materials. The following insights are based on all three studies.

The perceived benefits of a digital whiteboard application depend on the usage context and the situation of the user

When people see a benefit in a digital whiteboard system that neither analog tools nor other digital tools can offer, they are motivated to use the digital whiteboard system. While this is quite obvious, the particular benefits people see are quite diverse and perhaps not obvious at first glance. Through the studies, we encountered different needs in different contexts. Although, one may think the situation for company employees at distributed locations is similar, we found different situations, resulting in different needs Tele-Board could address and benefits Tele-Board could

offer to these users. Similarly, in the laboratory studies, there were users who saw a benefit in Tele-Board or the Synthesis Guide that was not available with their previous approach.

To give a sense for the variety of needs and perceived benefits compared to the situation before Tele-Board, I chose the narrative style of scenarios and needs formulation (Cooper et al., 2007).

- Satellite user at home office wants to structure meeting thoughts and have more informal exchange with remote colleagues. Before, he could only use audio conferencing and Powerpoint or e-mail.
- Employee at a small site wants to be involved in UCD activities as well, but has no team at his location. Before, he could only contribute via audio conferencing and was not really involved.
- Remote employees at other locations than their manager, want to present and discuss creative ideas and thoughts. Before, they had the challenge of conveying ideas via audio conferencing, or they had to use slide decks that were mistaken for finished concepts.
- Employee wants to collect feedback from colleagues on a concept that is not completely thought-through yet. Before, she sent around slide decks, which needed significantly more time because she wanted them to look presentable.
- Distributed team wants to take advantages of different cultural perspectives and bring in different user research and feedback data. Before, they could not tap the full potential of their international team.
- Manager wants to have more interactive and productive team meetings. Before, not all team members were involved, and there were less direct outcomes.
- Employee wants to take along whiteboard content easily, because he has to leave meeting rooms quickly. Before, he either did not use whiteboards or he had less time for the meeting because of clean up in the end.
- Design thinking coach wants to do more interactive DT introductions across distances. Before, she used web conferencing and was unaware of whether the participants were still following her and understood the content.
- Design thinking novice wants to learn best practices quickly through digital templates created by more experienced colleagues. Before he had to repeatedly consult training material and had no interactive recapitulation.
- Digital native wants to work in a fully digital environment without media gaps. Before, she had to find a way how to transfer the results on an analog whiteboard to a digital presentation and archival format.
- Design thinking project team wants to spend less effort and time for the documentation for their client. Before, it was a lot of work at the end of the project to collect all information.

- Synthesis novice needs guidance in the beginning and would like to have a sense of achievement earlier. Before, he did not know how to get started and was easily frustrated.
- Team that does not know each other very well needs a neutral tool to bring in more equality among team members. Before, the extroverts determined the way of conduct and the introverts were less engaged.

This episodic collection of user needs and situations should show the variety of different use cases that Tele-Board and the Synthesis Guide extension support. This variety may be a major factor for adoption, because it addressed the motivation of *different* people to make the effort to learn a new tool.

We saw that people in specific situations had more motivation to learn how to use Tele-Board than other users. For example, for employees who were located away from the main team and their manager – or even completely alone at their home office – an extra communication channel that supports informal collaboration was more important than for those with their colleagues next door.

Similarly, users new to UCD activities and the large amount of information after user research were pleased to use the Synthesis Guide and get advice on how to get started. In these situations, tools can offer extended support as has also been shown for ideation support tools (Wang et al., 2010; Shih et al., 2009).

When people saw no benefit in using Tele-Board or the Synthesis Guide, they were less willing to use it. Employees at the company, who saw the main benefit of Tele-Board in its support for remote work, said they did not need it when they were only working co-locatedly. Others, who regarded Tele-Board as a design thinking tool, said they would not need it because they were not conducting design thinking activities. Those more experienced with information synthesis and working in well-established teams saw no benefit to using the Synthesis Guide and would rather work without it.

A digital whiteboard system can help learning UCD methods

In the third study, we found that the Synthesis Guide especially helped participants who were rather new to design thinking activities. Subdividing the overall task and giving guidance on how to proceed was well appreciated. The tool can give advice for users new to all UCD methods, not only for synthesis. Several users from the company reported that the templates created by coaches or a more experienced colleague, were helpful because they did not yet have an extended design thinking training or they wanted to refresh what they learned in an online training. Although people agreed that on-site trainings are better than online trainings, there is often no possibility to bring coaches or participants to other locations. In these situations, an interactive tool could increase the learning effect and fun for the participants. We learned that Tele-Board was used as an e-learning tool for design thinking activities and helped students to remember and carry out different methods with the help of the templates that showed best practice examples.

However, research at the company revealed that Tele-Board was used more intensively by people who already had experience with analog tools. These users did not

have to get used to new methods *and* a new tool, but rather found ways to apply what they had learned in the digital environment. They also created the templates and best practice examples for other users.

We also saw that Tele-Board was introduced to new users while being used by their colleagues. Sometimes people explicitly showed Tele-Board's functions, but sometimes they just used it for their own work and shared their screen via web conferencing. While they were using it, others could decide whether they wanted to use it as well. We learned that it was important that people could also use Tele-Board "on their own" and were not dependent on co-workers who also used the system. This way, there was no disparity between the people who did the work and those who benefited (Grudin, 1994).

Collaborative tools for unstructured, informal ways of working are rare

From the employees of the company we heard that plenty of tools are available to them, but none support idea generation or working with unstructured data. This is also confirmed by Tim Brown, the CEO of the innovation consultancy IDEO:

> Too much has been focused on mechanical tasks such as storing and sharing data or running a structured meeting and not enough on the far messier tasks of generating ideas and building a consensus around them (Brown, 2009).

Even the tools also used for informal communication, such as chat or e-mail programs, constrain users to work in a linear way and are therefore less suitable for working with unstructured data. The ability to cluster pieces of information together was considered very valuable. Many other whiteboard applications do not support sticky notes and therefore no clustering of information. We think the combination of sticky notes and pen-input for sketching is useful and quite scarce in the range of tools available today.

Furthermore, we heard that standard office tools, such as Powerpoint, lead to perfectionism. When sending a slide-deck to colleagues, users feel pressured to send well thought-through, presentable work (cf. Chapter 5.3.3.2). Similarly, those working with design tools such as Adobe Photopshop rather tend to create polished, high-fidelity designs instead of quick concept prototypes. However, with approaches like design thinking, more and more companies are trying to incorporate quick iterations and low-fidelity prototypes in their product development life cycles again. The importance of sketching and iterations has been emphasized in UCD books and digital whiteboard research before (Buxton, 2007; Mynatt et al., 1999). However, often only people with a design background use sketches. Others may be inhibited about the quality of their drawings (Rogers et al., 2011), or they do not know which tool to use. A tool that by default does not impose how to layout content or dictate how the outcome should look, encourages input from all directions. If it is usable without special knowledge (as required for e.g. Photoshop) people without a design background are more likely to use it as well. An office tool that particularly supports informal collaboration, can therefore help to introduce an iterative work method on a larger scale.

Mobile devices could be the contributing factor for adoption

Digital whiteboard hardware is large, heavy, and expensive. Even though the acquisition costs for some devices are justifiable for a large company, we learned that the deployment of the large devices is not flexible enough for typical meeting room situations. Smaller companies may be hesitant to invest in hardware without knowing at which extent it will be used. Furthermore, even though the hardware has substantially improved during the last years, it is still not perfect. From the studies, we learned that tablets and smartphones are a good supplement for touch-based whiteboard interactions. In the first study, the iPads allowed each team member to sketch ideas as on paper notes and allowed parallel input that the whiteboards did not offer. At the company, mobile devices were not yet used, mostly because users did not know about smartphone or tablet apps. However, in the second round of interviews, several people told us that they owned a smartphone now and wanted to test the mobile apps. Especially the DT coaches were pleased to know that there was the possibility to sketch ideas and get away from laptop input. The mobile apps can be used while people are standing and offer less distractions than a laptop.

For the synthesis, mobile devices can also offer an extended support. The Synthesis Guide is a web application that can be accessed on smartphones as well. On their way to work, people could already tag the notes from user research and get acquainted with the notes written by their colleagues. Thereby, the mobile application can help the team to prepare for the synthesis beforehand and save time overall.

With the increasing pervasiveness of smartphones and tablets, input devices for informal collaboration are ubiquitous. Furthermore, people are more comfortable using them – as with a sticky note pad. We already observed this among the users in the first two studies: people who owned an iPad were pleased to use it for writing sticky notes. Mobile devices generally give more flexibility to work anywhere and anytime. Until now, UCD activities mainly limited teams to the same time and place. With mobile devices, they can write sticky notes in a similar way as before, but whenever and wherever they like.

7.2 Design Implications

From the findings of the three studies, I derived the following design implications for future whiteboard systems:

- **Flexibility** A digital whiteboard system should support different ways of working and different use cases. Users should be able to work both synchronously and asynchronously and easily switch between these modes. For example, it should support collecting ideas, sketching design concepts, or project planning in agile software development – and anything else that is possible at a traditional whiteboard.

- **Simplicity** While supporting different use cases, the system should still be simple and easy to use. Particularly for new users, the main functions should be easy to find and understand without instructions. More advanced functions should not importune new users.

- **Guidance** Especially for novices, systems can be valuable for learning new methods and ways of working because they can provide hints about what to do when and show best practice examples. Through templates and interactive exercises, a whiteboard system can offer additional digital benefits, unlike traditional tools.

- **Synchronization** For the majority of users, the main advantage of Tele-Board was the support of distributed work. Therefore, a tool should include the possibility to synchronize content in real-time between users. Concurrent input for all users at all locations should be granted. Additionally, synchronization between different services and devices is relevant. The success of cloud services has shown the importance of ubiquitous access to one's own data. Whiteboard systems should provide this as well.

- **Device-Independence** Users should not be bound to digital whiteboard hardware because it is often too expensive or not feasible to use in the respective situation. It should be possible to use pen- and touch-enabled devices as well as standard laptops. Each user should be able to use the device available and that he or she prefers.

- **Location-Independence** Users should be able to use the whiteboard system wherever they are. This includes subsidiaries worldwide as well as home-office. Furthermore, support for mobile devices can even involve colleagues during their commute.

See also Chapter 5.4 for recommendations for UCD tools in companies.

8. Conclusion

The research questions in the introduction have been addressed with the help of the three studies described in detail before. In summary, they can be answered as follows:

- **Does a digital whiteboard system support design teams during user-centered design activities in a similar way to analog tools?**

  The teams in the study could complete a whole design thinking challenge with Tele-Board and users were surprised how similar it was to analog tools. However, the way of working is different for some activities, mainly due to the hardware equipment. See Chapter 4 for details.

- **Which factors lead to the adoption of a digital whiteboard system in a corporate environment on a larger scale?**

  Different factors have an influence. Most importantly, the possibility to use the system in many different ways: in real-time remotely, co-locatedly, asynchronously, individually, for collecting feedback, for structuring ideas, for sketching, for project planning, etc. Furthermore, the simplicity of use for basic functions and the independence from special hardware are important factors. See Chapter 5 and 7 for details.

- **How can extended digital support help design teams at work?**

  It can give guidance to users who are new to design methods and help people prepare for team meetings in advance. See Chapter 6 for details.

A major goal of this thesis was to understand why digital whiteboard systems have not yet been widely adopted and which factors lead to or hinder adoption. We have learned that in corporate environments the required hardware plays an important role. In several former research projects, large display hardware was mandatory for using the respective application. However, we have seen how difficult it is to have these large and heavy devices available in different meeting rooms. The preparation needed is not feasible for a meeting. Another difficulty in company contexts is the

missing time and will for trainings in how to use the system. Employees already have access to a variety of tools and the disposition to learn another tool is quite low.

All three studies in this thesis have confirmed the main advantages of analog tools again: whiteboards and sticky notes are flexible enough to be used in a lot of different ways, it is not necessary to learn how to use them, and they can be employed ad-hoc, because they do not need to be turned on or have a charged battery. Especially for informal, unplanned use, these factors are crucial. Therefore, the benefits of a digital system for co-located use are often not high enough for the effort required. Additionally, we have learned that several people like "getting back to the analog way of working" because their usual work has them using computers most of the time.

Besides the difficulties of digital whiteboard systems, this thesis also addressed benefits of such a system and for which purposes it can be used.

Areas of Application

- **Remote work** This is the main use case for a digital whiteboard system. If team members cannot be together at the same location, a whiteboard system that allows real-time and concurrent input makes meetings more efficient and helps to conduct UCD activities over distances. It is particularly beneficial for users working from their home-office or users who work from other locations than the majority of their team and their manager (Chapter 5).

- **Remote trainings** UCD activities and processes are best trained and understood if they can be practiced interactively. If trainings can only take place remotely, a digital whiteboard system can make trainings more interactive and exciting for participants (Chapter 5.3).

- **Support for new users; preparation and post-processing** In co-located setups, digital whiteboard systems can make sense for those still learning UCD methods because it can give guidance and advice (Chapter 6). It can also save time if people can prepare for a meeting at home or while commuting. If whiteboard work is already digital, it is easier to save, document, and transfer the content to other digital formats (Chapter 4).

Necessary Equipment

The necessary equipment depends on the respective setup, task, and team size, as described in Chapter 5.4. In summary, a whiteboard application can improve collaboration even if it is only used with standard computers. With the help of mobile devices, which can serve as sticky note pads, users are not forced to sit in front of their laptops anymore. For a user experience that is more similar to the analog way of working, touch and pen-enabled whiteboard hardware is necessary.

Involvement of New Users

In Chapter 5.4, I gave recommendations for the introduction to a whiteboard application. In summary, it is crucial that users can perform basic tasks without training

or a manual. It should also be possible to work with the system in a meaningful way by oneself. This way, each user can decide how much time to invest in learning more advanced functions. Expert users may then encourage new users by showing how they work with the system.

8.1 Future Work

The studies in this thesis have mainly been analyzed in a qualitative way to understand the reasons behind user behavior and preferences. Although a large number of interviews and tests with several teams have been conducted, the findings may be different for other teams and users. In particular, the usage behavior and opinions from the company could differ largely in other companies. Therefore, further long-term studies of Tele-Board or another whiteboard application should be conducted. It could also be interesting to focus more on asynchronous work to find out how large time zone differences could be bridged more efficiently and conveniently. Tele-Board already offers a history view of whiteboard content. Later studies should investigate how much the whiteboard history helps to understand design decisions and whether video and audio recordings of the team work are still needed.

The Tele-Board users in the company study came from different countries and continents, and we observed different usage behavior between the locations. We assumed that the different behaviors were due to team structure, the location of the majority of team members, and the headquarters of the company. In the future, the role of cultural differences should be studied as well.

In Chapter 3.3.4 we have proposed two video setups in combination with the Tele-Board software. As described there, the overlay setup requires a dedicated camera position and is thus only feasible in a fixed room. From what we have learned, this would be difficult for a company context and the side-by-side setup is more likely to be used. In a laboratory experiment, the difference between the two setups for different tasks should be evaluated. They should also be contrasted to a co-located and an audio-only setup. Based on the work of Ishii and Kobayashi (1992) and Buxton (2009), we hypothesized that a reference space that allows deictic gestures on whiteboard elements is important for efficient collaboration. However, Tang et al. (2010) have shown that the reference space is not as important as thought before. They found that the shared task space was more important for solving the given task. These findings should be reviewed in the area of UCD activities.

We have learned that Tele-Board made DT trainings more interactive and helped to introduce DT to company employees. Therefore, the role a digital whiteboard system can play in e-learning in general could be investigated. That is, its usefulness in learning other methods and content, as it may increase the interactive participation.

With regard to extended support for different UCD activities, we have made a first suggestion as to how to support the information synthesis. Ideas for further research in this area were proposed in Chapter 6. As the extended support is only possible when working with digital sticky notes, future work should also deal with how to digitize paper sticky notes and make them available in the Tele-Board system.

A. One-Day Challenge Material (chapter 4)

A.1 Questionnaire for Study Participants

Testing Tele-Board

Gender: ☐ female ☐ male

Age:

Field of study/studies:

What was your first impression of the Tele-Board system?

_____

_____

I can imagine using the Tele-Board system for other Design Thinking activities.	
Strongly disagree ☐ ☐ ☐ ☐ ☐ Strongly agree	
Working with Tele-Board is useful for a Design Thinking challenge.	
Strongly disagree ☐ ☐ ☐ ☐ ☐ Strongly agree	
Our teamwork worked well.	
Strongly disagree ☐ ☐ ☐ ☐ ☐ Strongly agree	
Working with Tele-Board was fun.	
Strongly disagree ☐ ☐ ☐ ☐ ☐ Strongly agree	
Working with Tele-Board was too slow.	
Strongly disagree ☐ ☐ ☐ ☐ ☐ Strongly agree	
I would recommend Tele-Board to a friend.	
Strongly disagree ☐ ☐ ☐ ☐ ☐ Strongly agree	
Working with Tele-Board was complicated.	
Strongly disagree ☐ ☐ ☐ ☐ ☐ Strongly agree	
All team members were equally involved.	
Strongly disagree ☐ ☐ ☐ ☐ ☐ Strongly agree	

I was satisfied with our way of working.	
Strongly disagree ☐ ☐ ☐ ☐ ☐	Strongly agree
The Tele-Board functions were easy to understand.	
Strongly disagree ☐ ☐ ☐ ☐ ☐	Strongly agree
The existing functions are sufficient for whiteboard work.	
Strongly disagree ☐ ☐ ☐ ☐ ☐	Strongly agree
If I bought digital whiteboard hardware it would be a display board (black).	
Strongly disagree ☐ ☐ ☐ ☐ ☐	Strongly agree
If I bought digital whiteboard hardware it would be a projector board (with the colored pens).	
Strongly disagree ☐ ☐ ☐ ☐ ☐	Strongly agree
Working with Tele-Board works equally well as working with traditional whiteboards.	
Strongly disagree ☐ ☐ ☐ ☐ ☐	Strongly agree
If I had to choose I would prefer working with traditional whiteboards and paper sticky notes.	
Strongly disagree ☐ ☐ ☐ ☐ ☐	Strongly agree
The different ways of creating sticky notes is a valuable feature of Tele-Board.	
Strongly disagree ☐ ☐ ☐ ☐ ☐	Strongly agree
During this test we had more problems with team dynamics than commonly in design thinking challenges.	
Strongly disagree ☐ ☐ ☐ ☐ ☐	Strongly agree
Tele-Board is ready to use for Design Thinking projects.	
Strongly disagree ☐ ☐ ☐ ☐ ☐	Strongly agree

How do you evaluate the different tools for creating sticky notes?

Whiteboard	☐	☐	☐	☐	☐	☐
Keyboard (Laptop)	☐	☐	☐	☐	☐	☐
iPad	☐	☐	☐	☐	☐	☐
Tablet PC	☐	☐	☐	☐	☐	☐
Digital Pen	☐	☐	☐	☐	☐	☐
	Not useful				Very useful	Didn't use it

What are the major advantages of the respective boards, according to you?

Traditional whiteboards (analog)	Tele-Board (digital)

What are the major disadvantages of the respective boards, according to you?

Traditional whiteboards (analog)	Tele-Board (digital)

For which activities did Tele-Board work well? Why?

_____

_____

For which activities did Tele-Board not work well? Why?

_____

_____

Which Tele-Board functions do you consider most valuable?

_____

_____

Did you miss any functions? Which?

_____

_____

Do you want to tell us anything else? We appreciate every kind of feedback!

_____

_____

_____

_____

_____

_____

_____

_____

A.2 Questionnaire for Expert Evaluation

Video	What do you think: how helpful is the idea for the target group?	What do you think: how useful is the idea with regard to the needs of all stakeholders?	Have you ever thought about this idea before?
1	☐ Very helpful ☐ Quite helpful ☐ Somewhat helpful ☐ Barely helpful ☐ Not helpful	☐ Very useful ☐ Quite useful ☐ Somewhat useful ☐ Barely useful ☐ Not useful	☐ Yes, exactly in this form ☐ Yes, in about that way ☐ More or less ☐ No, but this may have been a coincidence ☐ No, I would never have had this idea
2	☐ Very helpful ☐ Quite helpful ☐ Somewhat helpful ☐ Barely helpful ☐ Not helpful	☐ Very useful ☐ Quite useful ☐ Somewhat useful ☐ Barely useful ☐ Not useful	☐ Yes, exactly in this form ☐ Yes, in about that way ☐ More or less ☐ No, but this may have been a coincidence ☐ No, I would never have had this idea
3	☐ Very helpful ☐ Quite helpful ☐ Somewhat helpful ☐ Barely helpful ☐ Not helpful	☐ Very useful ☐ Quite useful ☐ Somewhat useful ☐ Barely useful ☐ Not useful	☐ Yes, exactly in this form ☐ Yes, in about that way ☐ More or less ☐ No, but this may have been a coincidence ☐ No, I would never have had this idea
4	☐ Very helpful ☐ Quite helpful ☐ Somewhat helpful ☐ Barely helpful ☐ Not helpful	☐ Very useful ☐ Quite useful ☐ Somewhat useful ☐ Barely useful ☐ Not useful	☐ Yes, exactly in this form ☐ Yes, in about that way ☐ More or less ☐ No, but this may have been a coincidence ☐ No, I would never have had this idea
5	☐ Very helpful ☐ Quite helpful ☐ Somewhat helpful ☐ Barely helpful ☐ Not helpful	☐ Very useful ☐ Quite useful ☐ Somewhat useful ☐ Barely useful ☐ Not useful	☐ Yes, exactly in this form ☐ Yes, in about that way ☐ More or less ☐ No, but this may have been a coincidence ☐ No, I would never have had this idea
6	☐ Very helpful ☐ Quite helpful ☐ Somewhat helpful ☐ Barely helpful ☐ Not helpful	☐ Very useful ☐ Quite useful ☐ Somewhat useful ☐ Barely useful ☐ Not useful	☐ Yes, exactly in this form ☐ Yes, in about that way ☐ More or less ☐ No, but this may have been a coincidence ☐ No, I would never have had this idea

Now, please rank the ideas with regard to their usefulness for the needs of all stakeholders.

Video	1	2	3	4	5	6
Ranking						

THANK YOU!

B. Corporate Environment Study Material (chapter 5)

B.1 Interview Guide for Evaluation after Three Month

Using Tele-Board

- Please introduce yourself and your job role

Tasks / Way of Working

- How much has **your** way of working and **the team's** way of working changed since you had the workshops with us?
- For which tasks did you use Tele-Board?
  - Which ways of working did it support?
- For which tasks did it work well, for which ones not?

Common ground / ease of understanding, communication

- What were especially positive and/or negative experiences with Tele-Board and Design Thinking?
- Did you have more contact to customers?
- If you had more contact to external people (customers, consultants), was it easier to get an understanding of their point of view because of Design Thinking?
  - Any outstanding experiences?
- In which way did Tele-Board influence the mutual understanding or communication with your team members? Compared to merely telephone calls?
- In which way did the asynchronous way of working change?

Preparation / Setup

- How did you arrange a Tele-Board meeting? (MR? Or also in another way?)
- During the Tele-Board meetings, did you also have a video conference available? How often? Did you use the video?
- How many people were usually involved in the Tele-Board meetings? From how many locations?

Place of work / location

- At which location did you use Tele-Board (office, at home, on the way)?
- Which advantages and disadvantages did you notice in comparison to other tools?

Knowledge transfer / New users to Tele-Board

- How did you introduce and teach Tele-Board to other colleagues?
- With which functions did you start?

B.2 Interview Guide for Evaluation after 1.5 Years

Using Tele-Board

Intro

- Please introduce yourself, explain your current position, and tell us since when you have Design Thinking and / or Tele-Board experience

Tasks / Way of Working

- In which way has your way of working and the team's way of working changed since you were introduced to Design Thinking and to Tele-Board?
- For which tasks do you use Tele-Board?
    - Which ways of working does it support?
- Which hardware do you use? (desktop, laptop, tablet, smartphone, smartboard, ...)
- For which tasks does Tele-Board work well, for which ones not?
- Compared to other tools, which advantages and disadvantages does Tele-Board have?

Communication / Understanding

- With whom do you use Tele-Board (team, other teams, customers, ...)? At which locations?
- With whom would you like to use Tele-Board? Why doesn't it work?
- In which way did Tele-Board influence the understanding and communication with your team members? (Compared to audio call + desktop sharing?)
- In which way did the asynchronous way of working change?
- During the Tele-Board meetings, did you also have a video conference available? How often? Did you use the video?

Knowledge Transfer / New Users to Tele-Board

- How have you been introduced to Tele-Board?
- How did you introduce and teach Tele-Board to other colleagues?
- What were especially positive and/or negative experiences with Tele-Board and Design Thinking?

C. Extended Digital Support Study Material (chapter 6)

C.1 Interview Guide for Information Synthesis

Interviewfragen Synthesis Prozess

1. Wie werden die im User Research generierten Daten weiterbearbeitet?
    a. Wie wird eine Auswahl der Informationen getroffen?
    b. Wie entscheidet sich welche Ideen weiterentwickelt werden?
    c. Wie viele Leute arbeiten in dieser Phase zusammen?
2. Welche Arbeitsmittel (physisch und digital) werden verwendet?
    a. Welche Arbeitsmittel sind am wichtigsten?
3. Welche Anforderungen stellst du an die Arbeitsumgebung?
4. Wie bewertest du den Arbeitsablauf?
    a. Gibt es etwas, was dich am Arbeitsablauf stört?
    b. Was könnte man am Arbeitsablauf verbessern?

Translation of Interview Questions on the Synthesis Process

1. How do you proceed with the user research data?
    a. How do you make a selection of the information?
    b. How do you decide which ideas will be further developed?
    c. How many people are involved in this phase?
2. Which working material (physical and digital) do you use?
    a. Which material is most important?
3. Which requirements do you have on the working environment?
4. How do you evaluate the workflow?
    a. Is there anything that you dislike about the workflow?
    b. How could the workflow be improved?

C.2 Post-Task Questionnaire

Post-task questionnaire

Please answer the following questions with respect to the task that you just did

* Required

1. **Team No.** *

2. **Your No. (P1 - P4)** *

3. **Which challenge did you just do?** *
   Mark only one oval.
   - ◯ Airport challenge
   - ◯ Foreign researchers challenge

4. **How satisfied are you with the POV your team proposed?** *
   Mark only one oval.

	1	2	3	4	5	
Very satisfied	◯	◯	◯	◯	◯	Very dissatisfied

5. **How difficult was it to create the POV?** *
   Mark only one oval.

	1	2	3	4	5	
Very difficult	◯	◯	◯	◯	◯	Very easy

6. **How satisfied are you with your contribution to the POV?** *
   Mark only one oval.

	1	2	3	4	5	
Very satisfied	◯	◯	◯	◯	◯	Very dissatisfied

7. **How satisfied are you with the contribution of the other team members to the POV?** *
Mark only one oval per row.

	Very satisfied	Satisfied	Don't know	Dissatisfied	Very dissatisfied	That's me
P1	◯	◯	◯	◯	◯	◯
P2	◯	◯	◯	◯	◯	◯
P3	◯	◯	◯	◯	◯	◯
P4	◯	◯	◯	◯	◯	◯

8. **How much did your view on the data influence the POV?** *
Mark only one oval.

	1	2	3	4	5	
Very much	◯	◯	◯	◯	◯	Very little

9. **How much did the other team member's view on the data influence the POV?** *
Mark only one oval per row.

	Very much	Much	Don't know	Little	Very little	That's me
P1	◯	◯	◯	◯	◯	◯
P2	◯	◯	◯	◯	◯	◯
P3	◯	◯	◯	◯	◯	◯
P4	◯	◯	◯	◯	◯	◯

10. **During the discussions, how easy was it to understand your team member's points of view?** *
Mark only one oval.

	1	2	3	4	5	
Very easy	◯	◯	◯	◯	◯	Very difficult

11. **During the discussions: how similar was your understanding of the data to the understanding of your team members?** *
Mark only one oval per row.

	Very similar	Similar	Don't know	Not so similar	Not similar at all	That's me
P1						
P2						
P3						
P4						

12. **How well did you use the time you had for the task?** *
Mark only one oval.

	1	2	3	4	5	
Very well						Not well at all

13. **How satisfied are you with the process you used?** *
Mark only one oval.

	1	2	3	4	5	
Very satisfied						Very dissatisfied

14. **Did you always know what to do?** *
Mark only one oval.

	1	2	3	4	5	
Yes, always						No, never

15. **During the task, did you have the feeling you were on the right way?** *
Mark only one oval.

	1	2	3	4	5	
Yes, always						No, never

16. **Do you think a teacher was missing during this task?** *
Mark only one oval.

	1	2	3	4	5	
Yes, very much						No, not at all

	Conditions	
Questions	**unstructured**	**structured**
How satisfied are you with your contribution to the POV?	2.65 (0.94)	2.5 (0.93)
How satisfied are you with the contribution of the other team members to the POV? [P1]	1.52 (1.08)	1.5 (1.02)
How satisfied are you with the contribution of the other team members to the POV? [P2]	1.39 (0.89)	1.42 (0.97)
How satisfied are you with the contribution of the other team members to the POV? [P3]	1.43 (1.12)	1.38 (1.06)
How satisfied are you with the contribution of the other team members to the POV? [P4]	1.57 (0.95)	1.71 (0.91)
During the discussions: how similar was your understanding of the data to the understanding of your team members? [P1]	1.35 (1.07)	1.46 (1.14)
During the discussions: how similar was your understanding of the data to the understanding of your team members? [P2]	1.65 (1.03)	1.75 (1.36)
During the discussions: how similar was your understanding of the data to the understanding of your team members? [P3]	1.35 (1.03)	1.42 (0.97)
During the discussions: how similar was your understanding of the data to the understanding of your team members? [P4]	1.75 (1.16)	1.46 (1.06)
During the discussions, how easy was it to understand your team member's points of view?	1.78 (0.74)	1.88 (0.9)
How difficult was it to create the POV?	3.43 (0.95)	3.17 (0.96)
How satisfied are you with the POV your team proposed?	2.43 (0.9)	2.21 (0.93)
How well did you use the time you had for the task?	2.48 (1.2)	2.04 (1.16)
How satisfied are you with the process you used?	2.3 (0.88)	2.42 (0.93)
Did you always know what to do?	1.7 (0.97)	2.0 (0.93)
During the task, did you have the feeling you were on the right way?	1.96 (0.83)	2.13 (1.04)
Do you think a teacher was missing during this task?	4.13 (1.06)	3.83 (1.24)

Figure C.1: Mean values and standard deviations (in parentheses) for the post-task questionnaire.

C.3 Post-Test Questionnaire

Post-test questionnaire

Please answer the following questions considering all 3 challenges you worked on.

* Required

1. **Team No.** *

   .....

2. **Your No. (P1 - P4)** *

   .....

3. **Please rank the "common ground" or "being on the same page" among your team for the two challenges. I.e. in which challenge did you have the better common ground?** *

   Mark only one oval.

   - ◯ Airport challenge
   - ◯ Foreign researchers challenge

4. **In which challenge did your opinion influence the process and result most?** *

   Mark only one oval.

   - ◯ Airport challenge
   - ◯ Foreign researchers challenge

5. **In which challenge has your team been most efficient?** *

   Mark only one oval.

   - ◯ Airport challenge
   - ◯ Foreign researchers challenge

6. **Which challenge was most fun?** *

   Mark only one oval.

   - ◯ Airport challenge
   - ◯ Foreign researchers challenge

7. **Which of these two ways to create a POV from user research data do you prefer?** *

   Mark only one oval.

   - ◯ The 1st way
   - ◯ The 2nd way

8. **Why?** *
   Please give reasons for your choice

9. **Which way has which advantages and disadvantages?** *

10. **If you compare the ways to create a POV here and creating a POV as you are used to, which advantages and disadvantages do you see?** *

11. **Anything you want to add?**

C.4 Insights Questionnaire

Your insights

* Required

1. **Team No.** *

   .....

2. **Your No. (P1 - P4)** *

   .....

3. **Which challenge did you just do?** *

   Mark only one oval.

   - ( ) Airport challenge
   - ( ) Foreign researchers challenge

4. **Please write down YOUR most important insights (3+-) for the challenge you just did** *

   .....

   .....

   .....

   .....

   .....

C.5 Airport Challenge Comprehension Questions

Airport challenge questionnaire

Please give your answers based on the sticky notes presented here.

* Required

1. **Team No.** *

2. **Your No. (P1 - P4)** *

3. **Which airport do the interviewed people like?** *

4. **Which airport do the interviewed people NOT like?** *

5. **What kind of people are most annoying?** *

6. **Which problem(s) do people have with the smartphone check-in?** *

7. **What are the problems with waiting at the airport?** *

C.6 Foreign Researchers Challenge Comprehension Questions

Foreign researchers challenge questionnaire

Please give your answers based on the sticky notes presented here.

* Required

1. **Team No.** *

2. **Your No. (P1 - P4)** *

3. **According to the interviewees, which people do not speak English?** *

4. **Why should foreigners take German classes before they come?** *

5. **What are the differences in research between China and Germany?** *

6. **What are the advantages of doing research in Germany / Berlin?** *

7. **With which administrative task / authority did people have the biggest problems?** *

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