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DOCTORAL DISSERTATION

Techniques and Artefacts for Documenting Design Rationale Among Multidisciplinary Design Teams

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Abstract

In this PhD, I investigate the collaborative practices and digital tools used by design teams following a user-centered approach to create interactive systems. More specifically, I focus on how designers document design rationale and communicate it to team members of different disciplines. Previous research has shown that including a variety of actors and discourses into design activities stimulates creativity and innovation. Nevertheless, miscommunications frequently occur due to dissimilar priorities, vocabularies, and preferences. Consequently, designers must find ways to communicate the rationale of design solutions – what the solution is about and why it is appropriate in a given context.

While several tools have been proposed to document design rationale, they remain largely under adopted, since they tend to constrain and structure design thinking. This research responds to these challenges by investigating the collaborative practices of designers and proposing tools to document design rationale around design artefacts in a way that fits current work practices. In particular, I present three core contributions.

First, I uncover issues related to collaboration faced by designers, which are situated in multidisciplinary communication, information sharing, and documentation of design processes and outcomes. These issues expose design directions for tools to support the collaborative practices of design teams in a manner that respects their processes and working styles. Second, I present two tools that provide a low threshold approach to document design rationale and decisions. These tools activate team communication and enable creative design by providing a shared workspace to facilitate visual communication based on artefacts. Third, I demonstrate that our approach to design documentation allows rationales to emerge organically together with artefacts, and enables design teams to generate ideas in collaboration. Furthermore, the tools aid design teams to reflect on previous work and possible courses of action, which promote awareness and allow them to track design rationale and decisions over time.

Selected Publications

This thesis text is based on the following peer-reviewed publications.

Gutierrez Lopez, M., Rovelo Ruiz, G., Haesen, M., Luyten, K., Coninx, K. Re-thinking Traceability: A Prototype to Record and Revisit the Evolution of Design Artefacts. In *proceeding of the ACM International Conference on Supporting Group Work* (GROUP 2018), Sanibel Island, Florida, USA, January 07-10, 2018

Gutierrez Lopez, M., Rovelo Ruiz, G., Haesen, M., Luyten, K., Coninx, K. Capturing Design Decision Rationale with Decision Cards. In *proceedings of the 16th IFIP TC.13 International Conference on Human-Computer Interaction* (INTERACT 2017), Mumbai, India, September 25-29, 2017

Gutierrez Lopez, M., Luyten, K., Vanacken, D., Coninx, K. Untangling Design Meetings: Artefacts as Input and Output of Design Activities. In *proceedings of the 35th Annual Conference of the European Association of Cognitive Ergonomics* (ECCE 2017), Umeå, Sweden, September 20-22, 2017

Gutierrez Lopez, M., Haesen, M., Luyten, K., Coninx, K. Helaba: A System to Highlight Design Rationale in Collaborative Design Processes. In *proceedings of the 12th International Conference on Cooperative Design, Visualisation and Engineering* (CDVE 2015), Mallorca, Spain, September 20-23, 2015

Gutierrez Lopez, M., Haesen, M., Luyten, K., Coninx, K. Study and Analysis of Collaborative Design Practices. In *proceedings of the 4th Participatory Innovation Conference* (PIN-C 2015), The Hague, Netherlands, May 18-20, 2015

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1 Introduction

The main focus of this PhD is *supporting the collaboration of multidisciplinary design teams working in the user-centered design of interactive systems*. To this end, I investigate the work practices of these design teams, and propose solutions to document the rationale behind design artefacts while enabling creative design and activating team communication.

1.1 Motivation

Design is a *reflective conversation*, where "doing and thinking are complementary" (Schön, 1983, 1992): designers explore and transform ideas, appreciate the results of these transformations, and refine them in consequence. Design processes are seemingly disorderly and chaotic, and design problems are considered as "messy" (Schön, 1983), "ill-defined" (Simon, 1969), and "wicked" (Rittel & Webber, 1984). The reason for this is that design problems are by nature undefined and ambiguous (Cross, 2001). The implication of ill-defined design problems is that there is not one, correct way to resolve them.

Maher et al. (1996) describe that designers explore problems and solutions simultaneously, which means that they *co-evolve* in a gradual, iterative way. It is widely accepted that this co-evolution is a social process, as solutions emerge from an unconstrained, free flowing stream of ideas among the different actors (Warr & O'Neill, 2005). According to Dorst (2006), designers co-evolve problems and solutions by considering and connecting different points of view (or *discourses*). Exploring a variety of discourses stimulates creativity and innovation. Thus, the complexity and richness of design processes emerge from identifying, exploring, and prioritizing different points of view (Stolterman, 2008).

While the process of co-evolving problems and solutions is a source of creativity, its outcomes are hard to communicate. A source of miscommunications is the limited *common ground* between designers and stakeholders of the design process. As described by Clark & Brennan (1991), common ground requires "mutual knowledge, beliefs, and assumptions", and is thus essential for

communication and coordination. Miscommunications within design teams have a variety of causes, including the different disciplines involved, the specialized language used, and the dissimilar priorities and preferences of the different actors (Eckert, Maier, & McMahon, 2005). However, for a design solution to be considered as such, it must be accepted by all relevant actors of the process (Dorst, 2006). Thus, designers must find ways to communicate not only *what a design solution is about*, but also *why it is appropriate* in the context of a given problem.

In the context of this PhD, I am interested in how designers communicate the co-evolution of design problems and solutions with team members from different disciplines. However, each design discipline has particular practices and techniques. For instance, architects communicate with clients using artefacts such as detailed sketches, scale models, and CAD plans (Schmidt & Wagner, 2000), but this might not be the case for a graphical designer. For this reason, I focus on studying the practices and techniques of one specific type of design – *interaction design* – which is concerned with creating digital products *for* and *with* people (Löwgren & Stolterman, 2004). More specifically, my aim for studying interaction design is the *tension between the rational and creative aspects* of these projects, which has been acknowledged in previous literature (Fallman, 2003; Löwgren & Stolterman, 2004; Wolf, Rode, Sussman, & Kellogg, 2006). I seek to explore approaches that balance and take advantage of both aspects. Therefore, I explore both notions traditionally associated with engineering design, such as *design rationale* and *traceability*, and apply them to creative design processes.

1.1.1 Multidisciplinary Teams in User-Centered Design

Interaction design focuses on creating new interactive products to support the life or work of specific end-users (Rogers, Preece, & Sharp, 2011). Thus, interaction design involves *making* and *innovating* technologies (Fallman, 2003). However, this design discipline has particular challenges, which Stolterman (2008) articulates with typical situations faced by interaction design practitioners: *"[A] design task that is unknown or partially known, with demanding and stressed clients and users, with insufficient information, with new technologies and new*

materials, with limited time and resources, with limited knowledge and skills, and inappropriate tools."

These drawbacks have opened the need to investigate the theoretical, methodological, and procedural implications of interaction design (Stolterman, 2008). One of the scientific disciplines that has been active in such research is *human-computer interaction* (HCI). This discipline has a strong relation with interaction design, as both center on how people use technologies (Löwgren & Stolterman, 2004). While HCI has a broader spectrum, such as to address the computational, ergonomics, and cognitive aspects of technology, a substantial part of HCI research is design-oriented (Fallman, 2003), pointing towards the interactive aspects of technology. One of the approaches in HCI to further integrate design and research is *research through design* (RTD). This approach advocates for positioning design as a "legitimate method of inquiry" to produce scientific knowledge (Zimmerman, Stolterman, & Forlizzi, 2010).

HCI research in general and RTD in particular have produced very fruitful knowledge on how to integrate design into research, both on theoretical and methodological level. For instance, *strong concepts* to spread design proposals across specific contexts of use (Höök & Löwgren, 2012), and *workbooks* (W. Gaver, 2011) and *annotated portfolios* (B. Gaver & Bowers, 2012) to document design proposals and their evolution throughout the process were introduced. These approaches have gained traction to facilitate communicating design artefacts and the knowledge they contain to a broader audience. However, there is a gap when it comes to how this knowledge is applied and integrated into design practice in industrial settings (Colusso, Bennett, Hsieh, & Munson, 2017; Gray, 2016; Gray, Stolterman, & Siegel, 2014). A few reasons for this gap are:

1. Design practitioners face difficulties in understanding theories and applying methods, as they derive from scientific areas, such as social sciences, engineering, etc. These theories might require time or in-depth knowledge to master (Rogers, 2004). Practitioners will therefore struggle to fit these theories into their work practice as they are under constant time pressure, applying them in an *opportunistic* way (Gray et al., 2014).

2. Design practitioners face problems communicating their ideas to others, especially non-designers (e.g., clients or software developers), given a lack of common vocabulary or different priorities and interests (Rogers, 2004). Despite this challenge, designers constantly share ideas with others, and it is critical for them to negotiate their ideas effectively with people from different disciplines (Colusso et al., 2017; Gray, 2016).
3. Design practitioners focus on "commercially successful products" (Zimmerman, Forlizzi, & Evenson, 2007), in which satisfying the needs of a specific client plays a crucial role in fast-paced projects.

In this dissertation, I am interested in exploring the challenges related to (2) and (3), as I *focus on the particularities and constraints of doing interaction design among multidisciplinary teams.* Design practitioners create (viable) interactive products under tight deadlines and with limited resources, to satisfy specific client and user needs, while dealing with organizational requirements. However, not enough is known on how designers work in the field, or the role of technology into their everyday practices. Stolterman & Pierce (2012) point out that there is "surprisingly little work investigating how interaction designers think about their [digital] tools and the ways they use them." More recently, Dalsgaard, Inie, & Hansen (2017) noted that "research into role and nature of digital tools in collaborative creativity in professional practices is scarce and scattered". As a result, there is limited information on how designers use digital tools in their professional practice to "develop, capture, and manage ideas" (Inie & Dalsgaard, 2017), or how these tools could be better suited to support collaborative design (Dalsgaard et al., 2017; Stolterman & Pierce, 2012).

To address this gap in knowledge, I am concerned with investigating how designers work and the tools they use in order to propose technologies that are suited to support them. Particularly, there is a growing interest on how designers in industrial settings have applied techniques and tools of *User-Centered Design* (UCD) into their practice (Gray, 2016). UCD has been widely used in industrial settings as an approach to create interactive products that are useful and usable in a specific context (Mao, Vredenburg, Smith, & Carey, 2005). However, as mentioned before, more research is needed to understand how these teams work.

In this dissertation, I draw upon the definition of UCD proposed by Rogers et al. (2011), where it is employed as a broad term for interaction design techniques and procedures that place the end-user at the center of the design and development process of interactive systems. The concept of *user involvement* in these processes implies a "direct contact with users," and covers many approaches depending on its theoretical and practical interpretation (Kujala, 2003). In broad terms, user involvement could be located at any point on the *continuum* proposed by Damodaran (1996): from passively *informing* the process, to *consulting* on specific aspects, or *participating* actively in the decision-making process.

Different design teams use a different amount of user involvement and this may even change across the project, as this could be determined by factors such as organizational practices, level of expertise, and resources available. It is outside the scope this PhD to describe to what extent UCD teams include user involvement in their projects, or to propose techniques to facilitate participatory engagements. Instead, I focus on how we can *facilitate the communication and documentation of artefacts resulting from their design work*. I aim to facilitate this regardless of the user involvement of their activities, or what specific approach or technique they follow.

The reason for this focus is that regardless of their approach to user involvement, including users in the process is not an easy task for designers (Kujala, 2003). Thus, I assume that designers engage in design activities to the best of their skills and resources. I do not investigate how effective their design activities are, or the quality of their outputs. Likewise, I explicitly avoid trying to reframe the way their work, and do not propose techniques for guiding their design activities. Instead, I propose solutions that could be used as an "extra layer" on top their current work practices in order to support their communication and documentation in a lightweight way.

Another core focus of this PhD is the *multidisciplinary aspect* of design teams. I am interested in this aspect as one of the key aspects of interaction design is the involvement of a variety of people, disciplines, and perspectives. Stember (1991) indicates that the *multidisciplinary* aspect "involves several disciplines who each

provide a different perspective on a problem or issue." Similarly, Jensenius (2012) suggests that multidisciplinary teams involve people from different backgrounds who work together by bringing their specific knowledge to the team. Drawing upon this understanding, I use the concept of *multidisciplinary* to refer to people who bring a *different perspective and background* to the design process, and that *work towards a shared goal.*

I identify two key points of view in this processes: *designers* and *stakeholders*. As suggested by Löwgren & Stolterman (2004), in this PhD I use simple and broad definitions of these terms with the intention of making them applicable and adaptable to different contexts and situations. The terms *designers* and *design practitioners* (which I use interchangeably) refer to both trained designers and other professionals who perform interaction design as their core work. I want to emphasize that not only trained designers are involved in interaction design, but that other disciplines are also involved and face similar challenges as designers in the traditional sense.

I use *stakeholders* as an umbrella term, referring to a variety of people and roles involved in the design process. In contrast with the *designers*, they do not have a fixed role as "designers" in the team. In more detail, stakeholders can include: (1) *internal stakeholders*, co-workers who collaborate with designers in a project, such as managers, marketing experts, and computer scientist. Thus, their roles and skills could be complementary to those of designers. This definition of "stakeholders" is similar to the configuration for UCD teams proposed by ISO (International Organization for Standardization [ISO], 2010). (2) *External stakeholders*, clients, end-users, or domain experts who have a particular, well-defined role in the project, usually as paying customers, decision-makers, or recipients of the final product. These stakeholders could come from a variety of backgrounds, and their involvement could range from only informing to being key decision-makers in the process (Damodaran, 1996).

For the sake of clarity, in particular instances appearing in this dissertation I specify to which group of stakeholders I refer to (i.e., internal or external). This is done by describing their particular role, background, or other useful information about their involvement in the design process. These two groups of stakeholders

are equally relevant in design processes, as designers need to communicate and reach common ground with both in order to facilitate the acceptance of a proposed solution. Therefore, designers, internal stakeholders, and external stakeholders form what I call "multidisciplinary design teams," where each team member brings a unique perspective to solve a shared goal.

Following the *ISO for Human-centred design for interactive systems (9241-210),* the objective of UCD is to produce an interactive application to be deployed and tested with end-users (ISO, 2010). According to this standard, UCD processes follow iterative cycles consisting of the following phases: (1) understanding and defining the context of use of the application, (2) delineating requirements based on the needs of end-users, (3) producing design solutions according to the requirements, and (4) evaluating the solutions with the end-users in consideration of the requirements. These phases provide a high-level structure for the process and indicate that it is an iterative process. Despite the fact that the process is well-defined, it can potentially lead to contradictory outcomes in different stages. For instance, a requirement delineated in the second step might be rejected when evaluating with users in the fourth step.

1.1.2 Information Flow and Artefacts in User-Centered Design

The work of designers is often to create *artefacts* that represent a design, which is then materialized by other team members (Schön, 1983). Artefacts are "almost anything that provides a visual and spatial forum for design ideas" (Wolf et al., 2006). In this PhD, I use a broad concept of *artefacts,* as suggested by the authors above, for referring to "almost anything" that serves to represent, articulate, and externalize ideas within the design process. Artefacts are used by design teams to ground communication, embody knowledge, boost creativity, and justify design decisions (Schön, 1983; Wolf et al., 2006). Nevertheless, they provide only a partial representation of design work. According to Dorst & Cross (2001), the *turning points* taken by design teams to co-evolve problem and solution spaces in an iterative way contain the most valuable information about the experiences gained during the design process.

In UCD processes, artefacts include storyboards, personas, prototypes, and workflows, among others. These artefacts are often shared, in part or as a whole,

with clients, end-users, project managers, other designers, and software engineers. These artefacts, serve as communication leverage to glue different perspectives (i.e., people stemming from different disciplines), such as the ones present in UCD. Given their relevance in the process, documenting artefacts and the turning points that led to their creation is a common practice for designers, which they do so in both formal and informal ways. This documentation makes it easier to:

- Communicate the rationale of ideas,
- Produce a collection of design decisions and sources of inspiration, and
- Promote awareness and reflection about the generated knowledge.

While design documentation is an integral part of the process, it remains an area that is largely unexplored (Bardzell, Bardzell, Dalsgaard, Gross, & Halskov, 2016). Moreover, designers report problems in documenting and communicating design processes and their outcomes to people from different disciplines on a regular basis (Rogers, 2004). Several of the approaches that originate from research are not adopted, because they constrain the way designers think about or argument on their work (Horner & Atwood, 2006).

In response to these challenges and opportunities, this research explores how the documentation of UCD processes can be better supported to facilitate multidisciplinary communication, considering the messy and ill-defined nature of design problems. With this work, I attempt to tackle the challenges for documenting design rationale and at the same time stimulate multidisciplinary participation as well as creative thinking.

1.2 Research Aims

The research described in this thesis centers around three research questions. For the first question – *"What collaborative practices do designers use to communicate their design outcomes?*" – I engaged in different types of studies to map the field. I performed interviews, ethnographic observations, and workshops, framing my research within the broad HCI field, borrowing concepts from *design theory* and *computer-supported cooperative work* (CSCW) fields. For the second question – "*What tools should we create for documenting design outcomes based on existing*

collaborative practices?" – I followed a user-centered design approach, where I explore design alternatives, evaluate them, and iterate over viable solutions. Finally, for the third question, – "*What can we learn about documentation of ongoing UCD projects?*" – I introduce new concepts and findings based on explorations involving design practitioners and the prototypes we created. For evaluation purposes, I used both lab-based studies, and a long-term usage study of the prototypes.

1.2.1 What Collaborative Practices Do Designers Use to Communicate their Design Outcomes? *(RQ1)*

Sonnenwald (1995) suggests that collaboration in multidisciplinary design teams is better described as "contested collaboration." This concept emphasizes that these design teams involve people who use a variety of specialized terminologies and activities, and have different expectations and priorities with regard to the design process and its outputs. This implies that the points of view of some team members might contradict or challenge each other. This "contested" way of collaboration could result in disruptions to the design process or affect the quality of its outcomes.

In this PhD, I concentrate on investigating the *(contested) collaborative practices of multidisciplinary design teams who follow a user-centered design approach to the creation of interactive systems*. According to Schmidt (2014), the concept of practices "frames contingent activities as committed to criteria for correct conduct in the form of norms, rules, procedures, plans, etc." This implies that practices are more than activities or tasks, as they require a conscious engagement and motives for them to be performed. Furthermore, the concept of practices includes the *techniques* (i.e., applied methods and tools to accomplish an activity) and *skills* (i.e., qualifications and abilities) needed to perform a particular activity.

As a first step in my research, I explore the collaborative practices of designers by conducting two user studies. I use these studies to find meaningful ways in which technology could support these practices. First, a set of interviews with practitioners is used to gain initial insights on how design teams communicate, with whom, and what tools and artefacts are used (Chapter 2). Additionally, ethnographic observations serve to investigate the role of artefacts in design

meetings, which are coordination points where designers and stakeholders of the design project meet (e.g., clients, developers, and end-users (Chapter 3). The outcomes of these studies served to delineate five "design directions" that serve to inspire and ground design work according to the possibilities detected (Sengers & Gaver, 2006).

1.2.2 What Tools Should We Create for Documenting Design Outcomes Based on Existing Collaborative Practices? *(RQ2)*

The iterative and incremental nature of design processes implies that ideas are explored and expanded, but possibly also discarded or radically changed, making it harder to keep track of the rationale behind an idea. As suggested by Moran & Carroll (1996), *design rationale* is the *"documentation of (a) the reasons for the design of an artefact, (b) the stages or steps of the design process, (c) the history of the design and its context."* This definition emphasizes the relation between design rationale and documentation, and the evolution of design over time, which require to think about the design outputs in a reflective way. Since the eighties, there has been a plethora of research that proposes digital tools and notations to capture design rationale. However, many design practitioners are reluctant to adopt tools to record design rationale, since tools tend to formalize design thinking, which often results in constraints to creativity and innovation (Burge, 2008; Horner & Atwood, 2006).

I ground my work with existing research on design rationale and combine it with my own insights about collaborative design practices in order to propose tools to support the documentation of the design work. I seek to balance more formal approaches, like the ones that are proposed in software engineering with creative approaches. More specifically, *I explore ways to capture documentation that can be communicated to people from different disciplines, collaborating in a user-centered design process. At the same time, my approach ensures sufficient freedom in creating documentation to avoid constraining the design process.*

I propose two tools for supporting design activities, which are assessed with design practitioners to gain insights about their usefulness, and over which I iterated based on their feedback. First, *Helaba*, is an interactive prototype of a tool to capture communication streams and artefact evolution over time in a

shared workspace (Chapter 4). Second, *Decision Cards* are a lightweight format to document design decisions by including information on what a decision is about, why it was taken, and by whom (Chapter 5).

1.2.3 What Can We Learn about the Documentation of Ongoing UCD Projects? *(RQ3)*

The potential impact and usefulness of design rationale documentation can only be understood in an empirical and longitudinal way (Karsenty, 1996). Having an overview of how design rationale evolves over time can give an idea on how it can be used to *trace back* content that is generated and enable awareness of the activities of team members. While the concept of *traceability* has been largely used in design engineering domains, it has not been applied to creative design.

In this PhD, I adopt the concept of traceability to investigate how it can be contextualized to keep track of the *twists and turns* of the process. Traceability enables design teams to pinpoint where a certain element was introduced into the process, and explore the reasons for its ultimate adoption or rejection (Matta, Ribière, Corby, Lewkowicz, & Zacklad, 2001), which in turn could help to reflect on the co-evolution of design problems and solutions (Dorst & Cross, 2001). Similarly, I explore the concept of *awareness* (Carroll, Neale, Isenhour, Rosson, & McCrickard, 2003; Gutwin & Greenberg, 1999), which involves team members establishing and maintaining shared backgrounds, presence, tools, and resources for evaluating common outcomes.

With RQ3, I investigate how a tool for documenting design rationale can help and support UCD design teams. For this purpose, I evaluate Helaba and Decision Cards through a longitudinal study that followed a full UCD project, from initial idea generation to high-fidelity prototypes. This study investigates the perceptions of participants about the usefulness of the proposed tools, and exposes the collaborative practices that the tools enabled (Chapter 6). Furthermore, this evaluation serves to gain knowledge about the type of information documented during ongoing design processes, and how rationales are used during the project (Chapter 7).

1.3 Research Approach and Methods

The initial research proposal of this PhD was framed within the FP7 EU project COnCEPT (COllaborative CrEative design PlaTform) that brought academic and industrial partners together with design practitioners. The objective of this project was to create a web-based, collaborative design platform for early design phases. The COnCEPT platform envisioned to integrate a variety of collaborative design tools, like sketching, mood boards, and mind maps, with both synchronous and asynchronous communication tools. This responded to the lack of specialized tools for professional designers to effectively collaborate during the early stages of the design process, especially when working in remote settings (Dorta, Pérez, & Lesage, 2008; Hesmer, Hribernik, Baalsrud Hauge, & Thoben, 2011; Wang, Shen, Xie, Neelamkavil, & Pardasani, 2002).

My role in the COnCEPT project was to study the collaborative practices of professional designers with focus on the *early stages of the process*, using the insights gathered to *propose digital solutions* that were appropriate for supporting design teams and viable within the COnCEPT platform. As a result of my involvement in the COnCEPT project, my initial focus was closely linked to the topics and objectives of the project.

First, I concentrate on exploring the *early, conceptual stages of the design process*. The early stages of design processes are "by its very nature, a vibrant, creative and dynamic period" (Austin, Steele, Macmillan, Kirby, & Spence, 2001). These same authors indicate that *social interactions* are key in this stage, as sharing ideas and information is required to reach agreements on how to follow and lead the design process. According to Löwgren & Stolterman (2004), during the early stages of interaction design projects, designers and relevant actors, such as end-users and decision-makers, engage in "some kind of creative generation of ideas". Ideas reside initially in the "mind's eye" of a designer, as they are internal representations (Cross, 2000). The capability of designers to externalize these initial (often imprecise) ideas in a way that is accessible to relevant actors is what moves the process forward (Löwgren & Stolterman, 2004). Thus, *clear communication* is crucial to convey information to guide the process, and to

articulate the constraints and future possibilities even in an *imprecise* and *provisional* way (Stacey & Eckert, 2003).

Secondly, I focused on *designing and prototyping digital tools*. The requirements for these tools were partially guided by the COnCEPT project, as they should have the potential of supporting remote work in order to be feasibly integrated into the COnCEPT platform. Thus, I took into account remote collaborative work in the context of my design work, but it was not my main focus.

In part, this thesis reports on my research activities framed by the challenge put forward in the COnCEPT project. More specifically, I focus on exploring digital tools to support communication during the early stages of the design process, in consideration of its multidisciplinary aspect, and the fact that teams are frequently distributed. However, it should be noted that my PhD research activities and outcomes expanded significantly outside the scope of the COnCEPT project.

1.3.1 Guiding Research Activities

I apply the *principles of user-centered design* as an overarching approach to guide my PhD. This approach served to enquire the collaborative practices of design teams, and to transform the insights gained into suitable digital solutions in an iterative way. Thus, I draw upon methods within UCD that are synergetic with my own perspectives and insights. As suggested by Norman & Verganti (2014), I apply UCD as a "philosophy" under which innovation surfaces by involving relevant users and studying their activities. Corresponding with this philosophy, I followed the three high-level principles recommended by Gould & Lewis (1985) to guide my research: (1) having an *early focus on users and tasks* to involve the users from the start and throughout the design process. (2) Using *empirical measurement* to evaluate the design proposals with different artefacts and techniques, gathering the reactions of users. (3) Following an *iterative design,* to address the issues with the proposed solutions according to the input of the users.

I explored a variety of techniques to involve users at all stages in the design process: qualitative research, probing and prototyping design solutions, and assessing these solutions in controlled and realistic contexts. These techniques were interwoven with one another to suit the aforementioned principles of user-

centered design. Therefore, the UCD approach provided a backbone and a framework for informing different activities and techniques to form a coherent research process, maintaining the focus on the target users.

Figure 1 maps the order of the core research activities that were carried along the four years of my PhD, and makes the chronology of the work clear: activities overlapped, and were inspired and informed by previous ones. My understanding about the problem evolved as I explored alternative solutions in a gradual and iterative way, and prioritized what issues needed to be addressed.

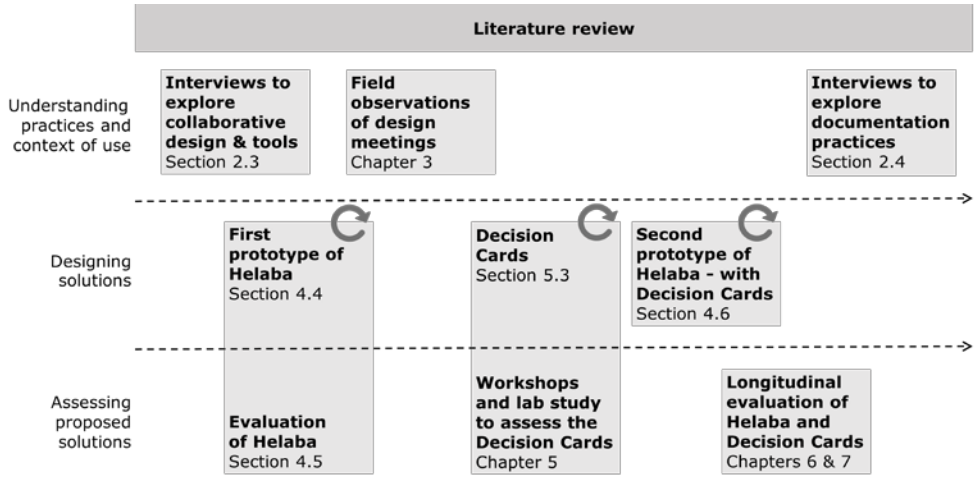

Figure 1. Core research activities in chronological order, clustered according to their goal: understanding the practices and context of use, designing solutions, and assessing the proposed solutions.

More than a representation of the relevance or duration of each activity, the blocks in Figure 1 illustrates the *chronological order of the core research activities* that are reported in this dissertation. These activities are clustered according to their goal (Figure 1, left): *understanding practices and context of use*, *designing solutions*, and *assessing the proposed solutions*. The dotted arrows indicate that each of the three main clusters of activities progressively informed each other. More than on the separate activities themselves, the knowledge was built on top of that gained in the previous activities. Accordingly, the insights gained in each activity were determinative to influence and progress my work. Along this process, I conducted a literature review to underpin my process with theoretical understandings, which also evolved together with my understanding of the

problem. The sections below present a narrative of the methods and techniques in each of these three clusters.

Understanding Practices and Context of Use

Qualitative research is useful to make sense of "how things work in particular contexts" (Mason, 2002) , as it serves to construct arguments from the point of view of the actors involved in a particular situation. As described by Flick (2009), qualitative research is appropriate when the goal of the research is to *discover* and *develop* empirical knowledge, more than to test existing hypothesis and theories. I used qualitative research across my PhD to reflect on design practices, where I gathered data, analyzed it systematically, and extracted knowledge about particular situations and contexts. The outcomes of these studies served to define design directions to inspire and ground design work with problems and opportunities that occur in the practices of users.

I used two main data collection techniques. Semi-structured interviews were used to investigate the first-hand *perceptions* and *accounts* (Mason, 2002) of designers about their collaborative work and documentation practices. Secondly, I used ethnographic observations to gather evidence of collaboration practices in the setting of occurrence. Thus, observations evidence knowledge that could be difficult to articulate during interviews (Mason, 2002). To ensure a systematic analysis of the data gathered in these studies, I used an inductive thematic analysis to generate the main themes, find connections among them, and interpret the patterns (Attride-Stirling, 2001; Braun & Clarke, 2006).

Designing Solutions Iteratively

The digital tools proposed in this dissertation – Helaba and Decision Cards – were conceived and evolved based on the insight and feedback from designers. The design work interwove with the qualitative research conducted to understand the practices of designers, and their assessment in an appropriate context of use. The process I followed was done in several iterations, as indicated in Figure 1, in which different ideas and concepts were explored. This approach fitted in an overarching UCD approach and facilitated my *design thinking and making* by linking knowledge generation with design inspiration, and by enabling me to communicate, reflect, and develop ideas with others (Mattelmäki, 2006).

More concretely, I used two prototypes of Helaba to explore different design alternatives, which were comprehensively assessed with design practitioners. Both prototypes of Helaba were useful to materialize the concepts and ideas in different stages, progressing from a rough initial prototype to a functional one which approximated a finished product (Sanders & Stappers, 2014). Both prototypes reflected at their core the problems faced by the design teams, but in making them my perceptions on how to solve them evolved, reflecting on new understandings of how to negotiate the problems and solutions which came through these prototypes.

It is worth noting that the second prototype of Helaba was built as part of a multidisciplinary effort: I took charge of the conceptual ideas behind it, while the technical implementation was led by a co-researcher with this expertise. I was closely involved in the implementation phase, as we collaboratively refined and transformed ideas into a system prototype that could be tested in a more extensive and realistic way.

The initial version of the Decision Cards prototype was used akin to *design probes* (Lucero, Lashina, Diederiks, & Mattelmäki, 2007) to provoke designers to create documentation using a lightweight format. This exploration lead to insights on how decisions can be documented by designers in the context of a design process. The Decision Cards were iterated inspired by these experiences, and its second version was integrated into the second prototype of Helaba to allow their assessment in an empirical and contextualized way.

Assessing the Proposed Solutions in Context

I assessed the proposed solutions actively throughout my design process, yielding insights into how they could be useful for designers, and inspiring directions to (re)shape their form and functionalities. Previous literature about the evaluation of collaborative systems in the field of CSCW suggests that it is important to situate the evaluation refined applications into the pertinent work settings and contexts (Pinelle & Gutwin, 2000). Furthermore, it highlights the challenges regarding the methods for collecting data over extended periods of time and usually in remote settings; the multitude of factors to be considered, such as individual, social, and usability considerations; and the validity of the evaluations

in a given setting to study the consequences on group interactions (Neale, Carroll, & Rosson, 2004).

In consideration of these challenges, I organized evaluations using a variety of techniques: from controlled lab studies to more realistic evaluations involving ongoing design projects over time. These evaluations were determined by the maturity of the solutions, as well as by what I needed to learn in order to make progress in the PhD research. For instance, the evaluation of the first prototype of Helaba was guided by scenarios in order to assess its initial concepts, while the evaluation of the second prototype was a longitudinal study which gave participants freedom to use the tools in a realistic context. Using a variety of techniques to assess the proposed solutions gave me an overview not only of usability and UI challenges to address, but also about the nature of social interactions that were enabled or even encouraged by these tools. The validity and limitations of these studies are addressed through this dissertation.

1.3.2 Research Collaborations and Outputs

I actively conducted qualitative research and design work within the COnCEPT project and the larger frame of my PhD. The Selected Publications section in this dissertation reveals the results of my contribution. All these publications have been published at international peer-reviewed conferences.

The papers included in the Selected Publications section are the basis for the Chapters 2 to 6 of this dissertation, which have been expanded with additional research work and insights. These five papers have been co-authored with supervisors and co-researchers at Hasselt University. Furthermore, Chapter 7 was written during a three-month research visit at Northumbria University, UK. The papers and dissertation contribute across the problem domain described in this work, as reflected in the section below and further elaborated in Chapter 8.

It is important to acknowledge that the research here described is a result of collaborative efforts which I have been part. Having the opportunity to be involved in multidisciplinary and collaborative research served to integrate and mature ideas by involving points of view which were complementary to my perspective and skills.

1.4 Contributions

This PhD presents the following contributions:

1. **An in-depth exploration of the practices of multidisciplinary design teams** when faced with challenges related to the documentation of ill-defined design problems and solutions. Our insights resulted in five directions to design systems to support creating design documentation for multidisciplinary teams.
2. **Two tools, Helaba and Decision Cards**, which capture design rationale documentation and design. I assess these tools with design practitioners using different evaluation techniques. The core contribution of these tools is a bridge between structured, rigid documentation and one which matches the free flow of ideas that characterizes the design process.
3. I contribute a **simple and lightweight approach to facilitate capturing design knowledge in an organic way**. This responds to the wicked problem of findings ways to create design documentation. I present a reflection on design rationale documentation, including a descriptive overview of what information is typically recorded, how this information is used during the initial stages of the process, and how it can be useful to support future design work.

1.5 Dissertation Outline

Part I is concerned with gaining insights in collaborative design and documentation practices, especially considering the early stages of UCD processes, and a reflection on opportunities to support these practices. Part II proposes new tools and approaches to support the difficulties and pitfalls that arise during the documentation of early stages of UCD processes. Part III describes the evaluation of the proposed solutions. Finally, Part IV reflects on these findings and their limitations, and suggests possible approaches for future research in this area. The remainder of this section introduces the four parts more into detail.

Part I. Insights into Design Processes and Practices

Chapter 2: *Exploring Collaborative Design Practices, Tools, and Documentation.* This chapter presents the results of a set of interviews to explore the collaborative

practices of multidisciplinary design teams, and how designers document and disseminate their design outcomes.

Chapter 3: *Artefacts as Input and Output of Design Activities.* I present the findings of in-the-wild observations where I investigate the role of artefacts to guide and document the outcomes of design meetings in multidisciplinary design teams.

Part II. Approach to Documenting Design Rationale and Decisions

Chapter 4: *Helaba: A Tool for Recording Design Rationale.* I discuss the iterative design, assessment, and implementation of Helaba, a tool created to document design rationale in an artefact-based workspace.

Chapter 5: *Decision Cards: A Format for Recording Design Decisions*. I present the iterative design and assessment of Decision Cards, a lightweight format to document design decision rationale.

Part III. Evaluating the Approach to Documenting Design Rationale and Decisions

Chapter 6: *Recording and Revisiting the Evolution of Design Artefacts.* This chapter reports on a longitudinal evaluation to explore the perceived usefulness of Helaba and Decision Cards in an ongoing UCD project. I discuss the implications for supporting for traceability of design rationale and decisions.

Chapter 7: *Information Recorded as Design Rationale using Annotations.* I present a thematic analysis of the content recorded by six groups of students in an ongoing design process using Helaba. I demonstrate that a digital tool with lightweight approach to design documentation could facilitate for designers to capture the creative aspects of their work.

Part IV. Reflections and Conclusion

Chapter 8: *Reflections and Conclusion.* This chapter includes a reflection on the findings presented in this dissertation. I discuss the implications and limitations of my work, open paths for future research, and finalize with a conclusion.

Part I: Insights into Design Processes and Practices

2 Exploring Collaborative Design Practices, Tools, and Documentation

The complexity of design and the lack of adequate tools to support design practice are well recognized in literature. Bridging this gap requires us to understand the practices of designers and to propose digital solutions that support their work without enforcing a different way of working. We take an empirical approach to understand the collaborative practices within design teams. In this chapter, we report on two studies involving professional design practitioners. The first study informs us about the collaborative practices and tools used by designers who follow a user-centered design approach for the creation of interactive systems. We reported this study in Gutierrez Lopez, Haesen, Luyten, & Coninx (2015). The second study describes how design researchers document and disseminate their design activities. We discuss the findings of both studies to highlight the importance of recording and keeping track of design work in a way that is suitable for stakeholders with a diverse background. As a final point, we present two *design directions* for interactive systems to support collaborative design practices.

2.1 Introduction

It is no secret that design processes can be very chaotic. As described in the Introduction chapter, there is a strong body of knowledge dedicated to understand and support design (design theory and research through design). In addition, a plethora of tools are proposed to support design, emerging from both research and commercially available software. However, existing digital tools to support interaction designers are not adequately grounded on an understanding of their practices (Rogers, 2004; Stolterman, 2008). More recently, Dalsgaard et al. (2017) argued that existing digital tools offer limited support for collaborative and creative work due to the insufficient grounding, and that they focus on individual usage (rather than on collaboration). The lack of appropriate digital tools is only added to the complexities of doing design, in which problems are ill-defined and solutions emerge organically from conversations between relevant actors (Dorst

& Cross, 2001; Warr & O'Neill, 2005). This implies that communication is challenging as it often requires negotiation among people from different disciplines (Eckert et al., 2005).

With these challenges in mind, we investigated the collaborative practices of design practitioners with a web survey. This survey, reported by Gutierrez Lopez et al. (2015), explores the professional and organizational practices, including tools used and challenges faced when collaborating. A total of 82 respondents, who identified themselves primarily as designers (89%), HCI researchers (62%), and project managers (46%) completed the survey. Respondents were active in the domains of interaction design, graphical design, and product design. The aim of this survey was to gather a broad perspective on collaborative design practices and digital tools to overview their salient problematics.

The results indicated that communication problems are more persistent than technical problems when it comes to creating artefacts in collaboration and informing team members about these artefacts. Some examples of the communication problems mentioned by the respondents are communicating progress and design decisions, while technical problems include versioning, tracking changes and difficulties to create and brainstorm remotely. The results of this survey echo those presented by Rogers (2004), where interaction designers working in the industry reported problems with multidisciplinary communication, and the need for better frameworks to disseminate design outputs to their teams and stakeholders.

The goal of this chapter is to investigate the practices and digital tools employed by designers when it comes to collaborating with their teams. To this end, we ground our research in the field of computer-supported cooperative work (CSCW), which conceptualizes that collaborative processes involve team members working towards shared goals, communicating to exchange information among them (Ellis, Gibbs, & Rein, 1991).

We conducted two user studies involving professional design practitioners. The first user study focuses on the question – *what major challenges in collaboration and communication are faced by design practitioners?* We conducted 22 interviews with design practitioners to map their overall collaborative practices and the tools

they use. This mapping was done using the *time-space matrix* (Ellis et al., 1991) to categorize collaborative activities according to its setting of occurrence (i.e., *where* and *when*). We use literature on CSCW to have an initial theoretical and practical underpinning on how to explore cooperative work, borrowing concepts such as *practices* and the *time-space matrix* to frame our studies. The findings from the first study allowed us to identify the communication streams that typically occur within design teams, and to pinpoint the bottlenecks. We found that documenting and communicating design outcomes is particularly challenging, and required.

The second study focuses on – *how do design practitioners cope with design documentation?* We interviewed 13 design researchers working in HCI, interaction design, and graphical design. We asked them how they document their design work, and to whom and how they disseminate it. We define *dissemination* as a specific type of communication to publish results, with focus on outcomes of the design process. The results of the second study indicate that designers do not follow specific or standardized ways of producing documentation, but have a variety of approaches that are applied according to the purpose of the documentation.

The findings of the two studies reported in this chapter are complementary, as they describe how designers externalize their design work in both remote and co-located settings. Considerations for supporting collaborative practices, as well as for documentation and dissemination of design practices, are formulated based on these findings.

2.2 Related Work

Design is intrinsically a social activity, as it sets out to perform creative and often innovative work in some kind of collaborative setting (Vyas, Heylen, Nijholt, & van der Veer, 2009). As described by Eckert et al. (2005), communication is an essential element in design activities. Designers communicate with people from different domains and with diverse interests, such as clients, end-users, engineers, and many others. Communication can be both formal and informal, taking different forms (verbal, visual, or textual) and can be happening in different settings (co-located and remote). Nevertheless, the complexity of design work

and the fact that creativity is not easily formalized or rationalized due to its experiential, artistic nature, may complicate its communication (Stolterman, 2008; Vyas et al., 2009). This is especially true for the conceptual stages of design, where teams generate and converge on ideas, while evolving incomplete, ambiguous design requirements into solutions (Détienne, 2006). Breakdowns in communication are a relevant field to study as they could potentially "lead to delays, mistakes and even the ultimate failure of this process" (Eckert et al., 2005).

Designers usually work in co-located settings (e.g., design studios), which have a "high material character" (Vyas et al., 2009). This implies that designers make use of their physical space to share design artefacts, such as sketches and prototypes. In turn, sharing a physical space can trigger inspiration and awareness about the ongoing activities of the project. While working in co-located settings, people establish and maintain awareness and common ground in a natural way, as face-to-face interactions facilitate mutual understanding over multiple channels (e.g., visual, auditory, and gestures), rapid feedback to overcome misunderstandings, and shared references over mediating artefacts (Carroll et al., 2003; Gutwin & Greenberg, 1999).

Nonetheless, design teams are increasingly often distributed geographically. Effective collaboration cannot just depend on sharing a common location. However, collaboration becomes more complex and "clumsy" as it shifts to remote settings (Gutwin & Greenberg, 1999). Several tools and approaches have been proposed in literature to overcome restrictions of remote collaboration in design, such as reduced field of view, limitations in exchanged information, and difficulty to establish informal communication remotely (Détienne, 2006). In this research, we study the collaborative practices that happen in both co-located and remote settings. To this end, we use the time-space matrix (Ellis et al., 1991) as a model to categorize the settings of occurrence (i.e., *where* and *when*) of designers' activities, outlining collaborative interactions along the place (co-located – remote axes) and time (synchronous – asynchronous axes). In this chapter, we use this matrix to categorize the collaborative activities of design teams according to its setting of occurrence. Table 1 illustrates the model as depicted by Dix, Finlay,

Abowd, & Beale (2004), classifying non-computer communication technologies in the matrix.

	Same time	*Different times*
Same place	Synchronous, co-located (face-to-face conversation)	Asynchronous, co-located (post-it note)
Different places	Synchronous, remote (phone call)	Asynchronous, remote (letter)

Table 1. Time-space matrix using examples from non-computer communication tools, as introduced by Dix et al. (2004).

Awareness is a key concept when it comes to conceptualizing collaboration. The concept of awareness involves "knowing who is 'around', what activities are occurring, who is talking with whom" (Dourish & Bly, 1992). Furthermore, awareness leads to a better understanding of the activities of others and creates a common ground among collaborators (Dourish & Bellotti, 1992). With better awareness of the activities of others, a designer will be able to more easily guide her own action within a shared environment.

Artefacts are a key for communication with and within design teams. According to Eckert et al. (2005), the "handover of information", where one designer delivers an artefact to another team member, is an essential aspect of the design process. A successful "handover" requires to reach a common ground, including a shared understanding of the elements of an artefact, which is in its turn instrumental to plan the design activities that follow. For this purpose, we engaged in a study on how designers document the artefacts they produce, and how they disseminate them to their team members. Surprisingly, there is little research dealing with the practical considerations of documenting design activities, for instance about what to document, to what extent, and how to balance efforts and benefits of its creation (Bardzell et al., 2016). Likewise, we find that research has overlooked the current practices used by designers to document their process, which could, in turn, give insights into dealing with the practical considerations described above.

According to Bardzell et al. (2016), design documentation is essential “raw material” to construct design knowledge during design processes. Documentation facilitates activities such as idea generation, communication, and evaluation. Documentation can take a wide variety of shapes and forms, such as prototypes, sketches, communication records, etc. The value of documentation is that it captures and externalizes the design knowledge that is contained in the artefacts (Sharmin, Bailey, Coats, & Hamilton, 2009). For Dalsgaard & Halskov (2012), some important benefits of documentation are: (1) supporting shared reflection and discussion during ongoing projects, (2) justifying why and how design decisions are taken, and (3) building knowledge across projects, which can be beneficial in the long term for designers and their team.

Difficulties in creating documentation are related to the fact that design is often unpredictable, which implies that information captured by the documentation can become invalid or out of focus easily. Schoffelen & Huybrechts (2013) showed that in the context of participatory engagements, “documentation of subjective viewpoints” (e.g., opposed to factual information), is not only underexplored, but that often people lack the motivation to document their viewpoints. In contrast, Sharmin et al. (2009) reported that despite these difficulties, designers are interested in tools for facilitating knowledge management, and for creating “a story” for the artefacts they create. Appropriate tools that serve to engage and generate outcomes which are valuable for designers have the potential of facilitating documentation (Schoffelen & Huybrechts, 2013).

2.3 Study 1: Investigating Collaborative Design

The goal of this study is to probe the collaborative practices of professional designers. We conducted interviews using mind maps and the time-space matrix to build an overview of how designers collaborate, with who, and where. We analyzed the maps and responses of participants in order to classify the collaborative practices according to the characteristics of the tools shared by design teams and stakeholders, either physically or virtually, and how artefacts are disseminated.

2.3.1 Methods

In total, 22 design practitioners (16 male, 6 female) from 15 different companies were interviewed. Participants ranged between 3 and 20 years of experience practicing interaction design. However, there was a variation on their backgrounds and perspectives. In detail, 15 participants identified as *designers*, with background in graphic, interaction, and product design. Four participants described themselves as *software developers*, but often undertook tasks related to interaction design. Three participants had the role of *project managers*, leading a larger team involving both designers and software developers. The selection criterion for this study was their active involvement in interaction design projects and teams. However, to ensure a broader overview of these teams, we included different perspectives: interaction, aesthetic, managerial, and technical.

Four participants worked in an academic institution, while the rest work in an industry setting. Fourteen participants were interviewed face-to-face at their office. Each of these co-located interviews took approximately 90 minutes, and were followed by an observation of the workplace. Eight participants were interviewed remotely (via Google Hangouts), and each of these meetings lasted around 60 minutes.

Interviews were conducted using a semi-structured protocol, which is available in Appendix A.1. These interviews were conducted with the intention of investigating the *perceptions* and *accounts* that participants articulated on their own words (Mason, 2002). At the beginning of the study, participants were briefed about practical considerations (e.g., privacy concerns and informed consent) and prompted to talk about their professional background and current work position. After this, participants were asked to create a mind map to aid them to visualize and reflect on their design practices. The mind maps were used to promote discussion, and to have a visual reference that could help identify missing elements or dependencies between them (Huybrechts, Dreessen, & Schepers, 2012; Wheeldon & Faubert, 2009).

Participants were presented with a visual representation of the time-space matrix on either a flipchart paper (face-to-face) or in a shared Google Drawings canvas (online). Taking account of the different settings of the interviews, both the matrix

outline and tools were designed to mimic each other, translating the physical ones (e.g., colored post-it notes) to resemble the digital materials (e.g., colored text boxes). The facilitator explained briefly the characteristics of each quadrant of the matrix, and introduced the tools available to create the mind map. Figure 2 shows examples of matrix outlines created during online (top) and face-to-face (below) interviews.

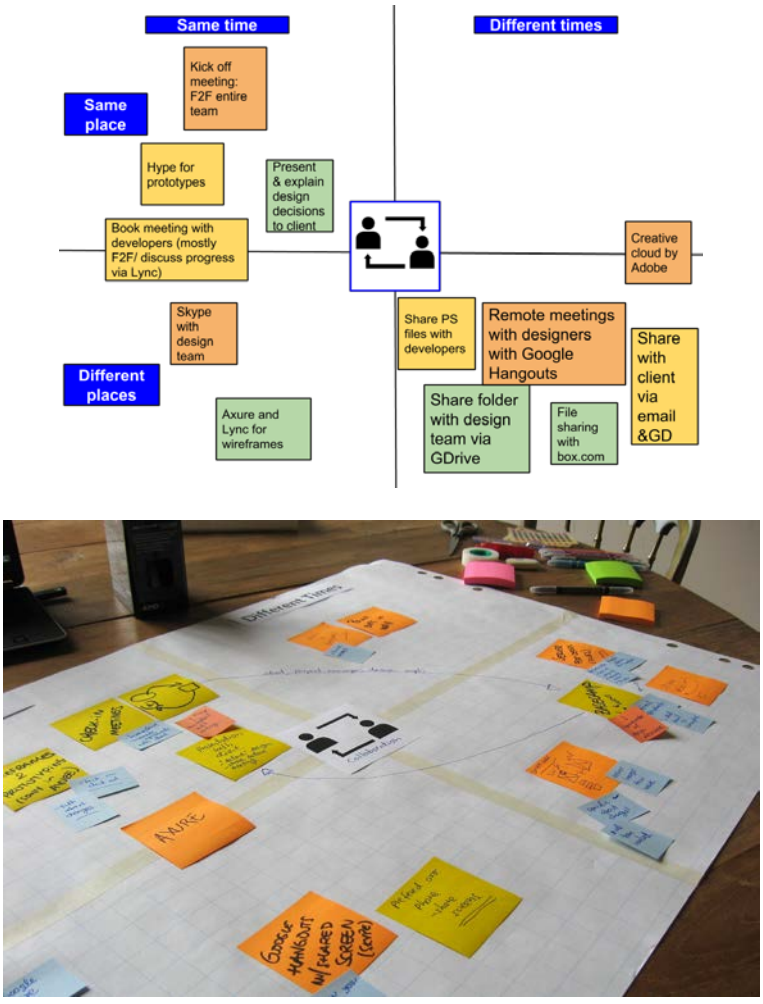

Figure 2. Examples of the mind maps created during online (top) and a face-to-face (below) interviews using the time-space matrix as a basis.

To start creating the mind maps, participants were asked to describe the early stages of a specific design project. Then, they were invited to use the available

materials to populate the mind map by adding keywords (e.g., tools, tasks, and challenges) to illustrate their collaborative practices within the time-space matrix. The facilitator of the session explained that there were no right or wrong answers, and also contributed by adding keywords and clarifications to the mind map. This was done to facilitate the creation of maps that were as detailed as possible in a constrained amount of time.

The audio transcript and finalized mind map of each interview were examined to search for recurrent collaborative design practices. As a first step, we collated the content of all mind maps into one unified map, keeping the time-space matrix format, in order to find what responses were recurrent among participants in each setting. Afterwards, we transcribed of the audio recordings.

We analyzed these transcripts together with field notes using an inductive thematic analysis to identify the main themes and sub-themes across the entire dataset. Finally, we linked the insights from the thematic analysis together with the unified map. Both data analysis techniques allowed us to identify patterns and draw conclusions about common collaborative practices, what tools are associated with them, and in which context are these tools used (e.g., synchronously or asynchronously). Below we report our findings, using quotes from interviews to illustrate the opinions of participants.

2.3.2 Overview of Digital Tools Used for Collaboration

The data collected from these interviews included a variety of tools and techniques that were discussed and captured within the mind maps. As suggested by Wheeldon & Faubert (2009), the mind maps were useful to guide discussion using a visual representation of the information shared by participants. Actively creating a map of their tools and techniques helped participants to recall other tools and techniques. This was particularly useful as the map grew, and participants felt inclined to complete the missing information.

The mind maps created by designers were visually and conceptually dissimilar to those described in literature (Eppler, 2006; Wheeldon & Faubert, 2009). Only a few maps created by participants showed clear relations or dependencies between elements. Instead, they focused on adding as much information as possible,

adding only a few pointers on how the tools and techniques were connected. Two finalized maps are illustrated in Figure 2. Participants were also guided to consider the time-space matrix to describe their collaborative practices. However, the characteristics of each quadrant of the matrix were not always clear for participants, and some were unsure on how to accommodate their tools or techniques. The facilitator prompted participants to accommodate them were they felt it was more appropriate, not where it was “correct”.

As a result, more than precise representations, the resulting maps present a rich overview of tools, and how they are fitted into their work. The techniques we used to gather information (i.e., mind maps and time-space matrix) facilitated for participants to visualize the information, and to reflect on their experiences. However, each participant decided how to use them during the interview, and the facilitator respected this by not forcing a specific end-result.

Table 2 presents an overview of the tools mentioned by participants, organized with as a rough categorization of recurrent collaborative activities: *communicate with stakeholders*, *create and edit artefacts*, *store and share artefacts*, and *team coordination*. On a high level, the data analysis showed that it is not the setting of occurrence or the particular tools that were determinant to pinpoint the collaborative practices and their challenges. It was *the outcome that designers wanted to achieve* (e.g., share information to others), and *the features of particular tools* (e.g., possibility to share screen) that pointed to the tools and strategies that they used to guide their work.

These rough categories of collaborative activities were mentioned in one way or another by each participant. This implies that all participants communicated with stakeholders, manipulated artefacts in different ways (i.e., create, edit, store, share), and coordinated with their team. Thus, the overview of digital tools can be seen as a comprehensive (but not exhaustive) list of tools used by professional designers, and their associated usage. In the sections below, we contextualize some these tools to the setting in which they are used, and we provide evidence on how they are used in practice.

Activities	*Digital tools*
Communicate with stakeholders	*Instant messaging, VoIP, and screen sharing tools:* Skype, Hangouts, HipChat, Lync, Whatsapp, Join.me, WebEx, Screenhero, Flashmeeting, internal chat application
	E-mail and conversation threads: Gmail, Outlook, internal e-mail client, Daylite, Slack, Basecamp
	Dissemination channels: blogs, wikis, project/company websites
Create and edit artefacts	*Synchronous editing:* Evernote, Google docs, Google drawings, and Google spreadsheets
	Word processors, spreadsheets, and presentation tools: MS Office and iWork suites, SharePoint
	Design tools: Adobe tools, Sketch, GIMP, Mural.ly, Flinto, Axure, OmniGraffle, Solidify, Tumult Hype, Balsamiq, Chopstick
	Data analysis tools: Dedoose, Atlas.ti
Store and share artefacts	*Centralized and cloud applications:* SharePoint, Basecamp, Daylite, GitHub, WeTransfer, Google Drive, Dropbpox, iCloud, Pinterest, Evernote, Box, internal file server
Team coordination	*Shared calendars:* iCal, Outlook, Google
	Task and team management: Daylite, Basecamp, Omnifocus, Trello, Yammer, TeamForge, JIRA, GitHub, Redmine, ConceptShare, Confluence, TurtoiseSVN, Doodle, Evernote, Illustrator, spreadsheets, Wunderlist, HiTask

Table 2. Overview of the digital tools included in the mind maps during the interviews.

2.3.3 How to Collaborate in Co-Located Settings?

When it comes to collaborating in a co-located setting, participants mentioned to have different strategies and tools depending on their audience. Thus, we describe our findings based on collaboration with internal stakeholders (e.g., co-workers as project managers, software developers, and other designers) and external stakeholders (e.g., clients and end-users). We expand on the differences between these styles of interaction in the sections below.

Collaboration with Internal Stakeholders

All participants mentioned to frequently interact face-to-face with their co-workers (e.g., project manager, developers, and other designers). This is hardly a

surprise, since teams were usually co-located. Likewise, all participants mentioned that internal collaboration and communication activities are often quick and informal, and take place on a daily and weekly basis. For instance, they frequently "pass by" their co-workers' desks to communicate changes, updates, or simply ask for their opinions. All participants mentioned that they did not plan these interactions, and simply preferred to follow a more natural way of collaborating. A limitation of these face-to-face, informal interactions is the difficulty of keeping a log of the topics discussed and agreements reached, as described by DP11, on the following excerpt: *"Most of the internal communication is just short meetings. We sit next to each other and talk. The only thing with this, is that there is no written transcript, and sometimes that can be a problem in a later stage."*

However, not all internal collaboration is done face-to-face. During our observations, we found that design teams use physical workspaces to post relevant artefacts, such as mood boards, sketches, or mock-ups for others to review and comment at different times. The value of this strategy is sharing internal knowledge serendipitously. For example, a designer of one of the design studios we visited mentioned to have the common practice of posting mock-ups on the wall to reach convergence between the graphic designer, the interaction designer, and the software developers. Figure 3 shows this shared mock-up on the physical workspace.

Figure 3. Public artefacts in co-located settings (such as this mock-up) can be used for internal knowledge sharing.

For this particular team, this practice of “posting artefacts” also facilitated communication using artefacts, as the different team members used different, mostly incompatible tools such as Photoshop, Axure, and HTML code. Having a way of displaying their work also promoted face-to-face interactions when required (e.g., clarify misunderstandings and propose alternatives).

Collaboration with External Stakeholders

Designers mentioned that they organize co-located interactions with external stakeholders who work in a different location, especially during the early stages of the process. Meetings are usually organized at project milestones, or when a design outcomes need to be disseminated. All participants pointed out that face-to-face interaction with stakeholders is one of the most valuable tools for designers. One reason for this is that face-to-face interaction allows them to identify and resolve possible miscommunications “on the spot”. Another reason is that they are able to sketch in collaboration, which facilitates stakeholders to participate in the decision-making process.

When it comes to face-to-face interactions with external stakeholders, designers use different techniques according to the type of design, organization, and personal preferences. Some of these techniques included co-creation workshops, kick-off meetings, and war rooms. The advantages of these interactions, especially with end-users and clients, were: (1) communicating ideas in a fast and easy way with sketches, drawings, and other visual aids; (2) identifying the needs stakeholders faster and more accurately; (3) helping stakeholders to “go through” or review design artefacts more efficiently (e.g., how to navigate through interactive HTML mock-ups); and (4) negotiating and reaching agreements with stakeholders to define the next steps for the artefacts and projects.

A limitation is the fact that face-to-face meetings with external stakeholders tend to be time-consuming. Moreover, designers also reported to have difficulties to accurately document these meetings. To overcome this limitation, each designer employed a unique combination of traditional and IT design tools. For instance, some participants preferred using their favorite pen and notebook, and their mobile to take pictures during meetings. Others chose to take notes in Evernote with their PC or tablet, combined with pen and paper to create sketches. The

commonality, regardless of the tools, is that designers wanted to: (1) focus on interactions rather than on technology, and (2) document the process as smoothly as possible. This was explained by DP10:

> *"I prefer using this [notebook] at a client meeting because it allows you to focus much more on talking with the client. I'm switching sometimes between my iPad and this [notebook] because sometimes I forget this, but I prefer this [notebook], because the screen glowing makes the other person feel like you're not paying attention."*

Designers invested time in creating documentation after a meeting in order to leave a record of the topics discussed and artefacts created. As an example, Figure 4 depicts DP10's pen-and-papers sketches "converted" to digital form, in order to facilitate sharing them with the client via e-mail.

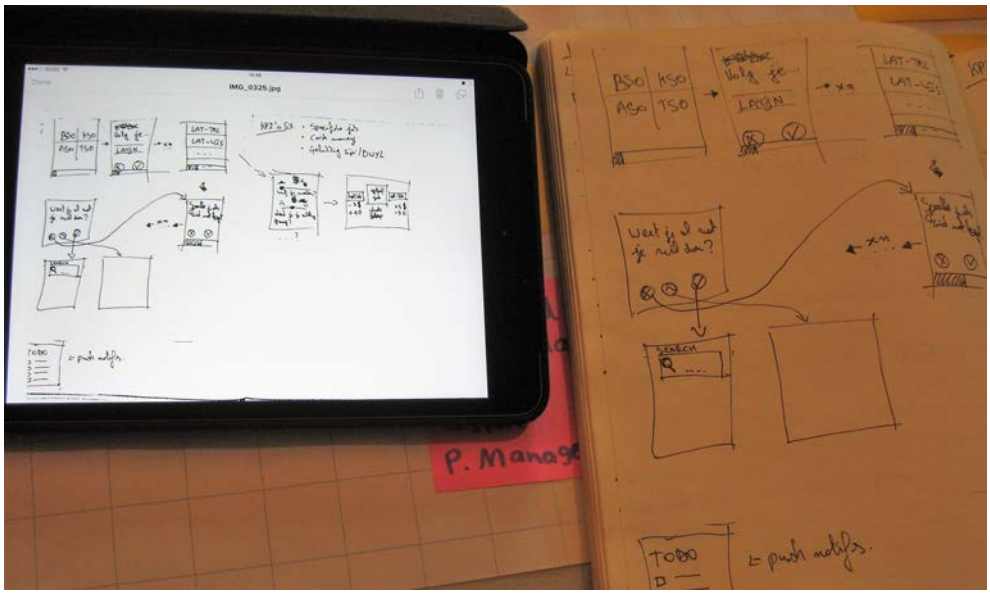

Figure 4. Sketches (right) transformed into digital documentation (left).

Participants described that the level of detail of this documentation ranged from rough sketches (as depicted in Figure 4) to polished designs, along with the progress of the project. As described by DP4, a strength of creating this documentation is to make others aware of their work: *"After meetings, I type these notes, and then I put it on Basecamp [...]. I share it with the client and my colleagues. So for instance, if I get sick, at least my colleagues know what the*

project is about and they can always find everything about the project." This quote reflects on the fact that the participant found it important to leave a record of their interactions, but also this record should be available to others, especially while remotely located.

2.3.4 How to Collaborate in Remote Settings?

All participants mentioned frequently communicating remotely with their stakeholders. The major benefit of sharing design outcomes remotely was to facilitate communication, especially in later stages of the project. For example, to share design updates to stakeholders in a quick way, as meetings can be time and resource consuming. Nevertheless, while remote communication was considered valuable for communicating and disseminating design outputs, it was not mentioned as practical for co-design activities, mostly because of limitations of the tools available for working at the same time in remote settings (e.g., lags while manipulating objects or lack of appropriate features to work synchronously).

When it comes to synchronous communication in remote settings, tools included VoIP and instant messaging tools, which are frequently used to share text, screens, videos, links, and files (PDF, Word docs, and images). Designers mentioned to have the common practice of sharing their screen with co-workers and stakeholders using popular and widely available tools such as Skype or Google Hangouts. This complements oral communication with a visual vocabulary while discussing certain design elements to quickly get feedback. An important limitation of using the videoconferencing/chat tools is that all (or many) team members must be users of the tool to make it useful. For clients, adopting a new tool can be an issue, for instance considering the limitation on permits to install software. For this reason, phone calls are still a common and valuable tool for communicating with stakeholders.

When it comes to remote, asynchronous communication, e-mail was the most mentioned tool. However, it was described as cumbersome to find previous conversations. A popular alternative is to use centralized applications, such as Basecamp and Daylite, as an effective approach to coordinate processes such as sharing artefacts and communicating while keeping a record of the project. These centralized applications include threads, annotations, and messages for clients

and designers to communicate. This is described by DP5: *"I really like it [Basecamp]… it keeps track of everything [...]. It's like a tape recorder, you know? All the decisions are in there. That's the discussion place, but also the deliverables' space. That's how I see it."*

Around 90% of participants mentioned sharing artefacts and receiving feedback by using cloud services, such as Dropbox or Google Drive, or internal file servers. However, uploading artefacts into a shared space was not enough for effective communication. To avoid miscommunications due to the lack of context when sharing artefacts, 95% of participants mentioned that they notify co-workers or stakeholders about updates using e-mail or chat messages. These updates often included a summary of modifications or a log file with relevant decisions or milestones to contextualize the design outputs. These tactics were mentioned as effective to some extent, but time consuming and confusing for some situations. A potential source of confusion is that they are not able to "point" to a specific part of the artefact directly. Another common tactic is to use the add comments/annotations to a file (e.g., in a PDF file). This makes it easier to "point" within the artefact, but this is only possible if it is a feature of the individual software.

Designers strived to have a way of organizing the files that are shared with others. Seven designers (35% of the participants) from four companies pointed out that their company had standardized protocols for naming and storing files, while the rest of the participants mentioned to do it according to what seems logical for each project or artefact. This issue highlights the difficulties in organizing artefacts and documentation, as most designers mentioned that organizing files is usually a "messy" task. This is illustrated by DP4, referring to the internal organization of templates for deliverables: *"We have templates [for deliverables], but it's a mess. It's always like, is this the latest one? [...] There are a lot of templates here. We're always working on projects, and it's a bit difficult to organize such stuff."* This quote reflects the fact that while there are efforts to organize the documentation, designers still find it difficult to cope with the tools available.

In the next section we discuss the implications of our findings for supporting the collaborative design practices which were reported as problematic.

2.3.5 Insights about Collaborative Design

The objective of the first study with designers was to explore the question: *what major challenges in collaboration and communication are faced by design practitioners?* To this end, we organized a set of interviews with professional designers to investigate the common practices and tools used to collaborate with co-workers and stakeholders. Our results indicate that *a core challenge is the communication of design artefacts, especially in remote settings*. We pinpoint two activities related to this challenge which are currently not adequately supported by technology: *documenting design communication and artefacts*, and *sharing an online workspace to contextualize design artefacts.*

Documenting Design Communication and Artefacts

Designers communicate on a regular basis with their co-workers and stakeholders. They found it relevant to keep a record of what is discussed and with who, but this was not always possible in informal communication (e.g., taking notes while discussing about a project over coffee with a co-worker). Moreover, when communicating with stakeholders, designers can find it problematic to reach a common ground for articulating what an artefact is about (Eckert et al., 2005).

In response to these challenges, our results showed that designers invest time and effort in documenting their design work in a way that captures its rationale "leaves a trace" of their interactions with other team members. For instance, carefully writing e-mails or documents that explained the rationale of their design, combined with the response of the recipients (e.g., feedback from external stakeholders). This strategy was used to avoid miscommunications that could take significant time and resources to correct, and to sustain and justify design decisions over time.

Sharing a Digital Workspace to Contextualize Design Artefacts

As mentioned above, designers invest time documenting and disseminating design artefacts. A strategy is to create a shared, digital workspace to communicate with others in a way that they can maintain awareness of the project serendipitously (Gutwin & Greenberg, 2002). Examples of these workspaces used by designers included Basecamp threads to add artefacts and conversations,

Dropbox folders to organize documents associated with a project, and Skype to share screens, creating a (temporal) workspace to disseminate artefacts. The value of these workspaces is that they integrate artefacts together with information about their rationale, either in a textual or verbal way, and emulate the material character of design (Vyas et al., 2009). However, they have limitations, such as not being able to "point to" specific aspects of an artefact, or facing difficulties when it comes to organizing and retrieving content.

In summary, designers use a variety of tools for communicating with their co-workers and stakeholders, both in remote and co-located settings. What seemed to determine what tool is used is not the setting, but the people involved and the goal to be achieved. The two core activities that we found were not adequately supported are: *creating documentation* and *sharing (virtual) workspaces*. We elaborate on these findings in combination with the outputs of the second study to define design directions to guide systems for these purposes.

2.4 Study 2: Investigating Design Documentation

The outcomes of the study described in Section 2.3 highlight the importance of documentation in the context of collaborative design activities. However, this study did not investigate how the documentation is created and disseminated. In this section, we present a follow-up study in which we interviewed design researchers to get better insights in their views on documentation, and how design documentation is performed in practice.

2.4.1 Methods

Thirteen design researchers (5 male, 7 female) voluntarily participated in this study. Participants had an average experience of 13 years practicing design, including disciplines such as interaction, product, graphic, industrial, and strategic design. All participants worked or had previous experience working in research institutes, mostly performing design research. Each one-on-one interview lasted around 60 minutes. Three interviews were conducted over Skype, while the rest were done in a face-to-face setting.

Participants were briefed about practical and privacy considerations with both participant information and informed consent forms. The facilitator used a semi-

structured protocol to guide the interviews (available in Appendix A.2). Participants were prompted to talk about their experience documenting and disseminating their design work, recalling specific situations or projects to contextualize their responses. While the interviews focused on the experiences of participants in an academic context, they were also encouraged to share their experiences working in industry. The last ten minutes of the session was devoted to gathering feedback about a prototype of an interactive communication tool for supporting designers. However, the insights given about this tool are not reported in this chapter. To conclude the session, participants were asked to fill in a questionnaire about basic demographic information.

All interviews were video-recorded, and notes were taken. The recordings were partially transcribed for further processing. We used an inductive thematic analysis to identify the salient categories in the data. Afterwards, as suggested by Attride-Stirling (2001), we used these categories to create "thematic networks", identifying and linking themes and sub-themes, exploring dependencies between themes, and finding the patterns that emerged from this exploration.

2.4.2 What is Documentation?

We asked participants to define what documentation is. All participants conceptualized documentation as a *purposeful* activity, being used as a *communication tool* and as a *reflective tool*. As a communication tool, documentation is created intentionally with the purpose of communicating the outcomes of the design process, having a specific audience in mind. This is illustrated by DP7*:"[Documentation] is any record that is kept and shared on a project. It's not individual sketches that a member of the design team just keeps for themselves […]." The key here is that documentation is something that is shared."* As a reflective tool, designers saw the value of documentation as a means of self-reflecting on their own experiences in a project. This was especially useful when working individually, as described by DP8: *"[Documentation is] more a personal reflection than anything else. Yes, we are trying to capture the thought… but at the end of the day, it's mostly for us, isn't' it?"*

Given its practical purposes, all participants mentioned documentation is a valuable activity for their design practice. Some of the benefits of creating

documentation mentioned by participants were: (1) materializing and articulating ideas about "what something is"; (2) evidencing design as an iterative process, guided by non-arbitrary steps; (3) supporting decisions and outcomes of the design process; (4) gathering focused feedback and provoking discussion; and (5) recalling previous ideas and decisions.

All participants mentioned challenges while documenting their design processes. What is more, 50% of the participants were somewhat negative when describing how they perceived their own documentation practices. This is illustrated with a quote by DP1: *"I just realized that my documentation habits are pretty terrible, but I think that's just me and how I work."* It is interesting that for DP1 (and other designers), the challenges in creating documentation pointed to problems in their own practice, instead of to the inherent complexity of documenting design. The most important challenges for creating documentation mentioned by participants were:

- *Too much information* is generated during the process, which makes it difficult to comprehend and organize the essential pieces of information.
- Documentation is *not integrated into the design process* itself, which means capturing it can slow down the process.
- Documentation *needs to be crafted for specific audiences*, and depends on the nature and stage of the project.

Despite the challenges faced when creating design documentation, all participants mentioned to invest time in this activity on a regular basis. The strategies articulated for creating documentation were mostly formulated as "what works for me is…" DP4 exemplifies one of the workarounds to deal with the challenge related to the amount of information generated during the design process:

> *"It's difficult [to document] because of the sheer mass of data: things that happen, decisions that are made both on big and small scale. They are just occurring constantly, and capturing those is a job in itself. And that's really difficult. Our way of getting around that is really simple. We just have a Dropbox, where we can put most things."*

The strategy described by DP4, as well as by the majority of the participants, was unexpected. The strategies described by participants were extremely simple and involved only basic tools, while in contrast they aimed at solving challenging,

ambiguous, and complex problems. This leads us to conclude that designers have an outspoken preference for a simple, straightforward approach for creating documentation, regardless of the task at hand.

2.4.3 How is Documentation Created?

Each participant had a unique strategy for creating documentation, which often varied within projects or stages of the process. Hence, we did not find one way for creating documentation, but a wide diversity of approaches. Common practices emerged, as described in the previous section, when designers discussed about the *purpose* of documentation (as a communication and reflective tool). We also discovered similarities when designers described the *content* of their documentation. Defining what content the documentation should cover depended mostly on the "philosophy" of the designer. For some participants, the documentation should contain *everything* that is created during the design process, while for others only *specific points* of the process seemed relevant to be documented.

Regardless of the covered topics, designers explicitly described the content of their documentation at two different levels of detail, as illustrated by DP11: *"I would take the best stuff from sketches and from Evernote [first level] to make a workbook [second level], which is a mixture between sketching and [using] Illustrator, and then put them in a PowerPoint deck."* Thus, we distinguish two types of documentation related to the level of detail of its content: *raw documentation*, which is mostly personal and unstructured, and *formalized documentation*, which is open to other persons and (more) structured. Characteristics of the two types of documentation are illustrated in Figure 5.

The vertical arrow in the figure above indicates that raw documentation is usually the starting point (at an earlier stage in the process), which was then iterated into more formalized documentation. In this sense, ideas that are more mature (over time), are more likely to be included in formalized documentation. However, there is no one-to-one relation between raw and formalized documentation, as not all raw ideas are elaborated into formalized ones.

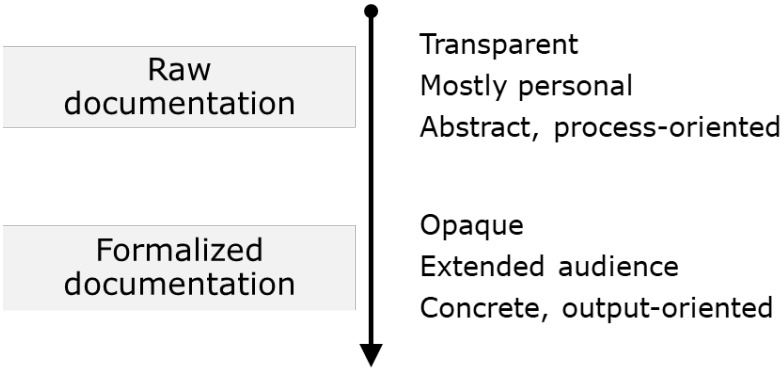

Figure 5. Types of design documentation according to the level of detail of its content: raw (top) and formalized (below).

In the sections below, we expand on the characteristics of each type of documentation, and the tools associated with their creation.

Raw Documentation

Raw documentation is a transparent record of ideas. We borrow the term of Bardzell et al. (2016), who describe documentation as "a key raw material" to construct knowledge. Our findings indicate that the content captured in raw documentation is abstract, informal, and to a certain extent, disposable. However, it has the advantage of being transparent, in the sense that it portrays the process as it happens. Examples included early prototypes and sketches used to explore initial ideas, notes taken during meetings and workshops, and diverse media used as inspiration (e.g., photos and videos).

Creating raw documentation is mostly a way to capture and reflect on ongoing tasks. For instance, participants mentioned taking photos during co-design workshops to capture relevant moments, or creating prototypes to reflect on alternative solutions. Given that raw documentation is *process-oriented*, it was created opportunistically, and mainly captures the process as it occurs. Raw documentation has a value for estimating *progression*, but not *significance* for the project or the final outcome. Thus, raw documentation was mostly used as self-reflection, and in some cases, to communicate with peers in an informal way.

Participants mentioned a variety of tools, used alone or in combination, to create raw documentation:

- Sketchbooks and notebooks (also mentioned as logbooks, scrapbooks, and journals);
- Digital sketchbooks and notebooks such as Evernote, Word, and Paper58
- Cloud and local storage services;
- Smartphones (e.g., to take photos and notes);
- Spreadsheets to relate content and context, timelines, etc.; and
- WhatsApp for quick and short communication.

One of the issues with raw documentation is that there are different bits and pieces (e.g., personal notes, inspiration sources, and prototypes) that are gathered or created across the different stages of the project. This means that organizing a coherent and progressive process requires designers to cope with a large amount of information. Five designers explicitly mentioned to have a very specific way to organize their raw documentation, such as mind maps or spreadsheets, adding dates and timestamps (to create timelines). This is the case for DP13, who mentioned a system for organizing his notebooks: *"I'm always drawing my ideas. I know where to find the ideas, but they are quite messy. I developed my own coding system. I know that if I underline something, it's something I don't understand, and I need to look for it."*

Investing a large amount of time in raw documentation can have the drawback of disrupting the flow of the design process. Furthermore, for some designers, investing time in creating or organizing raw documentation is potentially a waste of time, as they seldom consult it afterwards. The reason is that these raw ideas are less distilled or complete, and are often less useful in later stages in the process. However, some of these ideas are useful to record, since they keep track of the original intention of ideas.

Formalized Documentation

Formalized documentation is crafted to contain the learnings and relevant findings obtained during the design process. It is opaque in the sense that it highlights concrete outputs, rather than details of the process. Examples of formalized documentation include workbooks, academic papers, high-fidelity prototypes, and

reports. The primary purpose of these artefacts is to be communication tools, both with internal stakeholders (e.g., other researchers or managers) and external stakeholders (e.g., end-users, project consortium, or funding agency). Formalized documentation serves the purpose of *telling a (partial) story about the design process to a certain target audience*.

The level of detail of this type of documentation depends largely on the stage of the project, the anticipated audience, and the personal style of each designer. For instance, most of the participants agreed that the earlier stages of the project are documented with mostly raw documentation, which evolves into formalized documentation once that they have to disseminate their outputs to a larger audience. Similarly, all participants expressed the importance of having formalized documentation to "make their points come across" a larger audience. The value of this type of documentation lies in its *communicative value* and *significance* for the process. Formalized documentation that was meticulously created, is used to build trust and elicit conversations with a specific audience. Thus, it was expected to convey more about the efforts to generate quality outputs, than on the process itself. For instance, DP10 worked with *design sheets,* which were described as standardized A3 sheets used in a design studio to share formalized documentation with paying clients, including sketches and information such as date, version, and project:

> *"Design sheets are a perfect presentation of all the messy stuff you have been doing. You want to present the client something that has some polish, although sometimes you don't want to show something that is too resolved, too finished. You don't want to reveal that it was messy, or that you didn't know which way to go."*

As with raw documentation, participants mentioned to use a variety of tools, used alone or in combination, for creating formalized documentation:

- Specialized design tools (InDesign, Photoshop, CAD, Illustrator);
- Word processors and presentation software (collating text and images);
- Books and workbooks, A3/A4 printouts (either printed or digital);
- Social media: Instagram, Facebook, Tumblr, Flickr, Slack, and Pinterest;
- E-mail; and
- Cloud and local storage.

Participants frequently mentioned e-mails as a valuable tool for documentation, as they can be used to keep track of conversations and who was involved, and to share artefacts in context. Likewise, cloud storage services (Dropbox being mentioned the most) were used to create a space for the team and stakeholders, and to generate "peripheral awareness" (DP4) about the status of the project. However, keeping files organized and up to date in Dropbox can be challenging. Five participants had standardized ways to organize and retrieve artefacts either while working individually or taking part in project. Nevertheless, they still experienced difficulties while tracing back artefacts over time. This is illustrated with a quote by DP8: *"[In the] previous project, there was so much organization. We were very meticulously synching everything, and still there were things that we found difficult to reach […]. What I'm trying to say, even with so much attention, we found it difficult."*

2.4.4 Insights about Documentation

The aim of this study was to answer the question: *how do designers document their design processes?* We interviewed design researchers in order to explore their practices for creating and disseminating design documentation. Our findings point out that documentation is created with a specific purpose in mind, and that the content and level of detail is related to the intended audience and maturity of ideas. Below we describe the three core characteristics of documentation that were identified as the overarching themes in our findings. These characteristics reveal the key insights that we found while mapping and linking the themes related to the strategies for documentation mentioned by participants.

Relevant to a Certain Audience and Context

Documentation has a communicative value: it serves to contextualize design artefacts, and to situate different milestones in the project for various audiences. For instance, documentation that is shared with a peer researcher could result in discussion and provocation, while documentation that is shared with a funding agency could explain outputs in a convincing way to build trust. This contextualization is often done in retrospect (e.g., after the design activities are finished), and only reveal a part of the process.

Pragmatic in its Creation and Usage

Designers do not create "generic" documentation, but do so with a purpose in mind. This is illustrated by DP9, in the context of documentation as a communicative tool: *"I think I cannot do documentation for its own sake, it has to have a communicative purpose. Otherwise it's just a bit nebulous, just feels a bit pointless."* Documentation is considered as a resource that is actively created and used, thus serves a specific purpose. Likewise, documentation that serves as a reflective tool (i.e., to think about future possibilities) is more interesting for designers than a passive record.

Variable in its permanence

Documentation created very early in the process (which is mostly raw documentation) was less likely to be formalized. Raw documentation is useful as a reflective tool, as it captures where ideas emerge and presents an "honest" account of the design process, but it is seldom retrieved in later stages of the process. In this sense, efforts to maintain and index documentation are mostly invested when it comes to formalized documentation, created in a later stage of the project.

In summary, the level of detail and type of content were consciously decided by designers, as each participant rationalized why their documentation works (or fails) for either a communicative or reflective purpose. We found that there is no single way to create documentation, but that three high-level characteristics can be used to conceptualize it: *audience and context*, *pragmatic use*, and *variable permanence*.

2.5 Design Directions to Support Collaborative Design and Documentation

In this chapter we reported on our investigation of the practices and digital tools of designers who collaborate in multidisciplinary design teams. As suggested by previous research, we investigated these practices and tools for grounding new technologies to support their collaborative and creative work (Inie & Dalsgaard, 2017; Rogers, 2004; Stolterman, 2008). To this end, we set up two user studies with professional designers. The first study focused on *the major challenges in*

collaboration and communication faced by design practitioners. Our results indicate that documenting and communicating design outputs were bottlenecks in the process. Thus, we conducted a second study to investigate *how design practitioners cope with design documentation.* This study revealed the tension between creating documentation related to its purpose and level of detail. In this section, we explore two *design directions* for technologies to support collaboration and documentation according to the practices of designers. As proposed by Sengers & Gaver (2006), the design directions can delineate spaces and opportunities, pointing towards "directions for the development of new design possibilities."

2.5.1 Support Visual Communication

The value of visual communication has been long acknowledged in design practice (Buchanan, 1992). Artefacts are the basis of communication, and as such, they play a crucial role in reflecting knowledge generated during the process (Eckert et al., 2005; Wolf et al., 2006). We found that designers have experience and skills for communicating the ideas behind their artefacts with co-workers and stakeholders, as they described a variety of strategies and approaches which they considered useful, and mentioned that *communicating ideas efficiently* was part of their everyday work. However, doing this remotely remains challenging. For designers working in industry, breakdowns involved mostly miscommunications with clients, as designers have problems communicating visual ideas in a textual way (e.g., in an e-mail), and clients have problems evaluating design artefacts without adequate contextual information (e.g., why certain decisions were taken).

The participants of our studies described several strategies using remote visual communication, such as creating a Word document to share visuals and a decision log, using Basecamp to integrate images with conversation threads in a shared space, or creating a Dropbox folder to upload and share artefacts. However, neither of these tools is adapted for design work, which could cause communication breakdowns and additional work to make them fit visual communication. We believe that while communication of design outcomes can be difficult due to its messy nature, the documentation and (remote) dissemination of design work can provoke even more problems. Only a limited amount of issues

were raised with regard to explaining designs to stakeholders in a face-to-face setting. In contrast, a wider variety of problems were reported when this was done remotely. Our findings indicate that, for supporting collaborative design, it is relevant to facilitate the documentation and dissemination of design outputs. Although we found this to be a critical activity in our studies, it remains largely unexplored how designers document their work (Bardzell et al., 2016; Eckert et al., 2005). We propose to integrate design artefacts with the communication around them, in order to generate documentation that can be shared in a contextualized way, as described below.

Design Direction #1

We propose that artefact-based communication can be integrated as a means to support documentation of design processes. Artefacts should be contextualized together with their rationale and relevant conversations that led to their creation. For designers, the creation of documentation is more useful when created "in action", as a way that is integrated into their purpose, and has a value either as a communication or reflective tool. We suggest to integrate the communication that happens naturally in the team with the artefact, in order to generate a record of its rationale. Thus, the tool for documentation should be purpose-oriented in the sense that it streamlines into the communicative activities. We recognize that tools already manage artefact-based communication to an extent. However, there is a lack of tools that focus on the activities of designers, such as pointing to specific parts of an artefact. Furthermore, the tool should allow designers to contextualize the artefact at a specific point in the design process, and give an overview of previous versions or alternatives. This will enable awareness of the process.

2.5.2 Organize Large Amounts of Information

Designers generate large amounts of information, which has only increased with the usage of digital tools (Sharmin et al., 2009). When working in a co-located setting, designers can easily communicate ideas, using the physical workspaces to display artefacts that can trigger creativity and common ground. However, as design teams are increasingly distributed, they must find strategies to translate the physical interactions to a digital form.

Consistent with previous literature (Dalsgaard & Halskov, 2012; Sharmin et al., 2009), we found that some of the problems of generating large amounts of information is that (1) not all relevant information is recorded in an accurate way, (2) the organization of documents can be complicated. Consequently, designers actively curated what information to record and how to record it. For instance, they had different types of documentation: *raw* and *formalized*, and were quite certain about *what* they want to document and *when*. It could be counterproductive to introduce an approach that forces designers to document all artefacts, as they consciously select when and what to document. The downside of an approach that does not prompt users to create documentation is the potential loss of information, which is not captured due to lack of time, motivation, or not being identified as relevant initially. Thus, a potential solution should encourage designers to build a story, and make it easy and purpose-oriented. This could lead to capturing ideas serendipitously, regardless of whether they are ultimately integrated into design artefacts or discarded.

One way to support designers is to provide a shared workspace to organize and contextualize the information they decide to document. The organization of artefacts was especially problematic in those teams that share information with a variety of external stakeholders, such as clients or project consortiums. Likewise, contextualizing an artefact in a specific point of the project, or indicating its status was relevant. Awareness about the process is important to keep everyone on the same page, and to distribute knowledge.

Design Direction #2

We propose a shared workspace where designers can integrate artefact-based communication, but also where design artefacts can be organized and contextualized according to the status and stage of the process. Such workspace should facilitate for designers with retrieving their work or that of their co-workers. Furthermore, it will serve as a record of the design process, which is one of the objectives of design documentation. However, we believe that such a workspace should not structure or constrain the design process in any way. This could be done, for instance, by providing a “loose” hierarchy to artefacts, such as a folder system as in Dropbox (e.g., having one space for each project or task).

2.6 Conclusion

As stated in the Introduction chapter, this PhD concentrates on investigating and supporting the collaborative practices of interaction designers to communicate their design outcomes to multidisciplinary team members. In this chapter, we report on our two user studies involving a total of 35 professional designers who gave us insights on their work practices. These studies included a variety of professional designers working in both industry and academic contexts. This allowed us to gain a broad view of collaborative and documentation practices.

First, we explored the tools and practices used by professional designers to *collaborate with their stakeholders in both co-located and remote settings*. Afterwards, we investigated the practices of design researchers when it comes to *documenting and disseminating their design outputs*. The findings of these two studies highlighted the value of recording and keeping track of design work, especially for communicating with a wider audience. Furthermore, this chapter lists a variety of digital tools that are used in different settings, giving details on how some of them are used in context. From this list of digital tools, it is clear that designers tend to prefer conventional, off-the-shelf tools to facilitate their collaborative practices and create documentation. What is interesting here, is how they combine these tools to achieve their desired outcome.

Building on these results, we pinpoint two *design directions* to support multidisciplinary collaboration. The first direction is to *support visual communication* to facilitate capturing artefacts contextualized with their rationale and relevant conversations that led to their creation. The second direction is to *organize large amounts of information* in a way that is relevant for design processes, and that facilitates retrieving and sharing design outcomes with other team members. Tools that follow these design directions could enable a shared workspace that centralizes interactions around artefacts, and facilitate the documentation of design processes in an organic way. In order to have a better grasp on how artefacts are used to mediate collaboration, Chapter 3 reports on ethnographic observations to clarify the role of artefacts in co-located interactions. The design directions in this chapter and those emerged from the ethnographic observations are used to explore potential solutions in Part II of this dissertation.

3 Artefacts as Input and Output of Design Activities

As described in Chapter 2, artefacts are vital to communicate design outcomes, both in remote and co-located settings. However, it is unclear how the artefacts are used to mediate direct contact between designers and stakeholders of the design process. The purpose of the current chapter is exploring how professional design teams use artefacts to guide and capture discussions involving multidisciplinary stakeholders while they work in a co-located setting. This chapter is an extended version of the research published by Gutierrez Lopez, Luyten, Vanacken, & Coninx (2017). We report the observations of six design meetings in three different projects, involving professional design teams that follow a user-centered design methodology. Meetings with stakeholders are instrumental for UCD projects. However, design teams face the challenge of synthesizing large amounts of information, often in a limited time, and with minimal common ground between meeting attendees. We found that all the observed design meetings had a similar structure consisting of a series of particular phases, in which design activities were organized around artefacts. These artefacts were used as *input* to disseminate and gather feedback of previous design outcomes, or as *output* to collect and process a variety of perspectives. We discuss the challenges faced by design teams during design meetings, and propose three design directions for interactive systems to facilitate artefact-based communication in multidisciplinary design teams.

3.1 Introduction

User-centered design approaches ill-defined problems by focusing on the needs of end-users, which is considered to promote usefulness and usability of the resulting systems (ISO, 2010). However, UCD approaches are not without challenges or criticism. One of the critiques is that systems are designed “before use”, implying that the characteristics of a system are defined before actual usage occurs (Pipek & Wulf, 2009). The design-before-use critique is especially relevant

when designing systems that connect a large number of heterogeneous users, with usage styles and contexts of use that designers cannot anticipate.

Another critique is that the design output might not reflect on the most appropriate solution for a given problem, but one that was more readily accepted by the client or beneficiaries of the process (Cockton, 2013b; Jung & Stolterman, 2012). As reported in our previous studies (see Section 2.3), designers tend to be well-aware of these challenges, and tackle them as much as possible with different strategies. One such strategy is to organize co-located meetings together with *external stakeholders* (e.g., clients, end-users, and project consortium) in key moments of the project. Design meetings are collaboration points where designers engage in reflective activities together with stakeholders of the design process (Détienne, 2006; Olson, Olson, Carter, & Storrosten, 1992; Stempfle & Badke-Schaub, 2002).

A property of these meetings is that they enable face-to-face interactions between the design team and stakeholders. During design meetings, critical decisions are made to advance the design process (Dekel, 2005; Walz, Elam, & Curtis, 1993). Although design meetings occur in a specific point in the process and occupy only a small fraction of the project, they are instrumental, even determinative, for the direction of designs (D'Astous, Détienne, Visser, & Robillard, 2004). Thus, analyzing design meetings helps us to understand the interplay between the people and resources present.

In this chapter, we report on six design meetings involving professional, multidisciplinary teams where the overarching topic was the early design of an interactive system. We analyze what kind of activities are organized in these meetings, who is involved, and what the similarities are among different teams and projects. We expand on previous literature by focusing on the structure of meetings from the perspective of designers. Furthermore, we focus on how artefacts are used to guide the activities and discussions.

3.2 Background

To contextualize the activities and people involved in design meetings, we explore the multidisciplinary aspect of design and the role of these meetings in the design

process. Design is recognized as a social, collaborative process (Warr & O'Neill, 2005). In UCD, this collaboration extends to external stakeholders of the design process, such as end-users and clients (ISO, 2010). The inclusion of these stakeholders aims to obtain the best possible outcome from the design process. However, this inclusiveness also implies that people with different perspectives must strive towards achieving the same goal, which is designing a useful, usable system, which is ultimately *worthwhile* in its context of usage (Cockton, 2006).

We contextualize this diversity of people involved in UCD processes with the notions proposed by Fischer et al (2005). These authors make a distinction between "Communities of Practice" (CoP) and "Communities of Interest" (CoI) within design projects. Communities of Practice are groups of people who share similar domains, work, and knowledge. Thus, Communities of Practice have an existing common ground that can be used to communicate with ease (Clark & Brennan, 1991). However, common ground can also become a limitation due to the potential lack of disruptive ideas. Communities of Interest, on the other hand, integrate people from different disciplines and perspectives. What brings together a Community of Interest – which can be formed by various Communities of Practice – is a shared interest in attaining a goal, such as solving a design problem. Given the implicit diversity within Communities of Interest, they are an ideal ground to stimulate creativity (Fisher et al., 2005; Warr & O'Neill, 2005). Despite its value, interweaving Communities of Practice brings about challenges for design. For instance, it is required to establish a common ground to facilitate collaboration. Furthermore, while it is an objective of the Communities of Interest to "make all voices heard" in the process, it is not a straightforward task in large communities (Fisher et al., 2005).

Fischer et al. (2005) suggest the utility of boundary objects to foster collaboration among Communities of Interest due to their actionable and evolving nature. According to Star (2010), boundary objects are "a sort of arrangement that allows different groups to work together without consensus." Thus, within Communities of Interest, boundary objects allow teams to synchronize their efforts in a shared arrangement. Within UCD, such boundary objects include both conceptual and tangible artefacts, such as end-user requirements and prototypes (Fisher et al., 2005; Walz et al., 1993). These artefacts contain flexible representations of ideas,

and are useful to externalize different perspectives. Analyzing the process for "making and using" an artefact points to the connections between teams and other artefacts (Jung & Stolterman, 2012). Thus, *we explore design meetings as collaboration points between different Communities of Practice and Interest, where artefacts act as boundary objects to solve design problems*.

We identify two types of meetings that can occur in the scope of UCD projects: *design meetings* and *evaluation design meetings.* Design meetings involve co-design activities, where different actors contribute with their own point of view and skills to achieve a common goal. According to D'Astous et al. (2004), during evaluation design meetings designers externalize the outcomes of the design process, justify its rationale, and generate ideas to solve potential issues. Therefore, evaluation design meetings usually involve key stakeholders of the design process, such as clients and end-users, but are not traditionally associated with co-design activities.

In their seminal paper, Olson et al. (1992) analyzed collaboration in early software design meetings. They found that design meetings have a defined structure, although they seem chaotic and informal. This structure is consistent across different teams and topics (Olson et al., 1992; Visser, 2009). During the meetings, most of the time is spent in discussions about design issues. These discussions serve to generate and evaluate alternative ideas. Other recurrent activities involve "going over" what has been discussed using walkthroughs and summaries, making clarifications about design issues, and coordinating activities to manage both the project and the meeting itself (Olson et al., 1992). We extend the existing literature by investigating the structure of design meetings as they happen in-the-wild, using the agendas created by designers as input to investigate how teams organize and coordinate design activities.

3.3 In-the-Wild Observations of Design Meetings

We observed a set of design meetings in professional, real-life settings. Our study involves a total of six meetings that took place in the scope of three different design projects. Each of these projects applied a UCD approach to solve a complex design problem, including the redesign of a two governmental websites, and an

airspace management system. We observed two client-driven paid projects in a Flemish design consultancy firm and one research project at a university.

The inclusion criteria for selecting the observed teams were: all projects involved both novice and experienced designers, extended over the timespan of several months, included design challenges that required multiple iterations, and comprised many actors and resources. Table 3 gives an overview, including details about the meetings' duration and number of participants.

	Duration (in hrs.)	*Number of participants*	
		designers	*stakeholders*
Design consultancy			
Airspace management project	6 (day 1)	3	11
	7 (day 2)	3	15
	6.5 (day 3)	3	7
Governmental website project	3 (day 1)	2	6
Research institute			
Social care services project	3 (day 1)	2	4
	2.5 (day 2)	2	4

Table 3. Overview of observed design meetings and participants.

3.3.1 Participants

The designers involved in these meetings had a variety of skills and expertise levels, with experience ranging between 8 months and 15 years. Designers shifted between various roles according to their communicative behavior during the meetings (Sonnenwald, 1995). The *lead designer* was the senior member of the design team, who had the goal of ensuring that meeting objectives were completed, and the *backing designer* supported the lead designer to achieve this goal. We refer to the entire team of designers who participated in each meeting as the *design team*. We borrow the terms "lead" and "backing" from popular music, where backing vocals accompany the lead singer (Oxford Dictionaries,

2018). With these terms, we want to convey that backing and lead designers aimed to be *in harmony* during meetings.

The other attendees were *external* to the design team. They were key decision-makers or other team members who would be directly impacted by the new system. The observed design meetings included people with a variety of backgrounds and organizational roles, such as end-users, managers, and technical and domain experts. We give details about the attendees of each session in the sections below. During design meetings, they collaborated with designers to attain shared goals, such as generating and evaluating design alternatives. Hereafter, we refer to this group as the *stakeholders*.

3.3.2 Design Projects and Meetings

Next, we present an overview of the projects, meetings, and design teams involved in our study.

Airspace Management Project

The design team consisted of three designers: a lead designer with 10 years of experience (LP1), and two backing designers with 1.5 years and 8 months of experience respectively (BP1 and BP2). The goal of this project was to design a new system to improve and bridge the air-traffic control activities that were managed by two separate systems. The new system was expected to control the operations of a variety of actors across different departments of the organization. The external stakeholders group included: end-users (air controllers and similar roles), and project managers from a variety of divisions. A meeting was organized over three consecutive days. The first two days of the meeting focused on extracting and discussing the work practices of the target end-users and how the existing systems support them (or fail to do so). The third day of the meeting dealt with synthesizing the outcomes of the previous two days.

Governmental Website Project

The design team involved two designers: the lead designer had 15 years of experience (LP2), and the backing designer 1.5 years (BP3). The goal of the project was to redesign a multilingual website for a governmental institution. This project had a limited scope, involving only the front-end design and evaluation. A

design meeting was organized to discuss potential design alternatives for the layout of the website with external stakeholders, including project managers of different divisions, a software developer, and web content editors. The goal of this meeting was for the design team and stakeholders to ideally select one suitable layout solution for the website.

Social Care Services Project

The design team consisted of two experienced designers: a lead designer with 10 years of experience (LP3) and a backing designer with 7 years of experience (BP4). The goal of this project was to create a prototype for a governmental service to offer assistive technology for impaired users. Two non-consecutive meetings with external stakeholders, which involved physiotherapy and revalidation science experts (three researchers/practitioners and a professor), were held to gather feedback on artefacts created and to generate new ideas for a next iteration.

3.3.3 Methodology

Study Procedure

Our focus is on analyzing how design meetings are structured, and on the artefacts and techniques that are used to mediate collaboration between the design team and the stakeholders. Exploration of design meetings in professional, real-life settings allow us to capture realistic design practice as the starting point for the concepts and techniques we will propose in this PhD research. We used an ethnographic approach for these observations (Lazar, Feng, & Hochheiser, 2010). This approach was useful to gain “first-hand” experience about interactions as they happen in the field (Mason, 2002).

The observer had a passive role during the meetings, not intervening in any way in order to avoid disrupting or influencing the group processes. As suggested by (Flick, 2009), the observer focused on documenting the “actions and interactions” that took place during the meetings. Before each meeting, the observer informed all meeting attendees about her research objectives and role in the meeting, and asked their consent to be recorded on audio and video during the session. After the meetings, whenever possible, the observer asked the designers for

clarification about certain activities or events in order to improve her understanding and reduce possible misinterpretation.

Data Gathering and Analysis

Design meetings were audio and video recorded. The recordings were accompanied with notes, artefacts, and photos collected during the observations. We partially transcribed the videos for analysis. We examined the activities of the meetings on a higher level instead of utterance-by-utterance. This approach was taken because of the complexity of the data: very often more than one person spoke at the same time. This inhibited full transcription of all conversations. Therefore, we created a chronological *activity log* based on these transcripts. We focused on transcribing the utterances and communicative acts that captured how designers handled the meeting (e.g., how they introduced the activity, explained evaluation criteria, and settled conflicting opinions). The resulting activity log was complemented with details about goals, tasks, team roles, artefacts, and outcomes of each activity. These details allowed us to identify the overall structure of the meetings.

We categorized each activity in the log with a coding scheme according to the objective of the activity. This coding scheme was analogous to the one proposed by Olson et al. (1992). Similar to these authors, we identified and categorized the moments of the activities that involved “project and meeting management.” These were, for instance, coordination moments to organize the activities by stating their purpose, or to clarify the status of the project by presenting a timeline. When engaged in design activities, we identified moments where designers used “summaries” and “walkthroughs” to recap discussions, and when they encountered “digressions” (i.e., when the discussion deviated). Additionally, we found that designers frequently stated the “goals” in order to progress the activities more fluently, and made “clarifications” to avoid or correct misunderstandings with stakeholders.

Differently from Olson et al. (1992), we coded the moments when designers talked about “issues”, “alternatives, and “evaluation” as *problem-solving*. Thus, we clustered these three codes simplifying them into a single code, but kept their original meaning. The moments coded as problem-solving involved the points of

the meeting where designers or stakeholders articulated a design problem, proposed alternatives, and evaluated them against relevant criteria. Additionally, we identified categories related to the *team roles* assumed by designers (document session, facilitate activity), *source of the information discussed* (generated, retrieved), *spaces* (arrange, refine), and *artefacts* (validated, amended, created).

After coding all meetings, we compared the coding categories used in each activity within the different meetings. For example, activities categorized as project/meeting management tended to precede those of problem-solving. As a last step, we matched our activity log with the *agenda* of each meeting. These agendas were the schedules used by designers to coordinate each meeting. This step was useful to refine the activity log, using the agendas as a guideline. We utilize these agendas as a source for reporting on the structure of the meetings, as described in the next section.

3.4 Structure of Design Meetings

In-depth analysis of the chronological activity logs generated from our observations showed that different meetings follow a similar structure. This is consistent with previous literature on design meetings (Olson et al., 1992). The structure we found consisted of an interplay between three phases: *preparation*, *introduction*, and *design*. Figure 6 provides an outline of the agenda for each observed meeting, which we annotated with the specific techniques that were used during the meeting.

The structure shown Figure 6 was consistent across the different meetings, regardless of their differences in context, topics, and duration. However, the phases were not necessarily executed in sequential order. The design teams repeated or alternated between phases as required, even reiterating over preparation and introduction phases. For instance, the preparation phase was more prominent immediately before meetings and during breaks (i.e., coffee breaks), but also took place during design activities when the design team felt the need of “regrouping” to coordinate their activities more efficiently. The structure was not arbitrary though, as design teams deliberately used these phases to organize their activities and make progress.

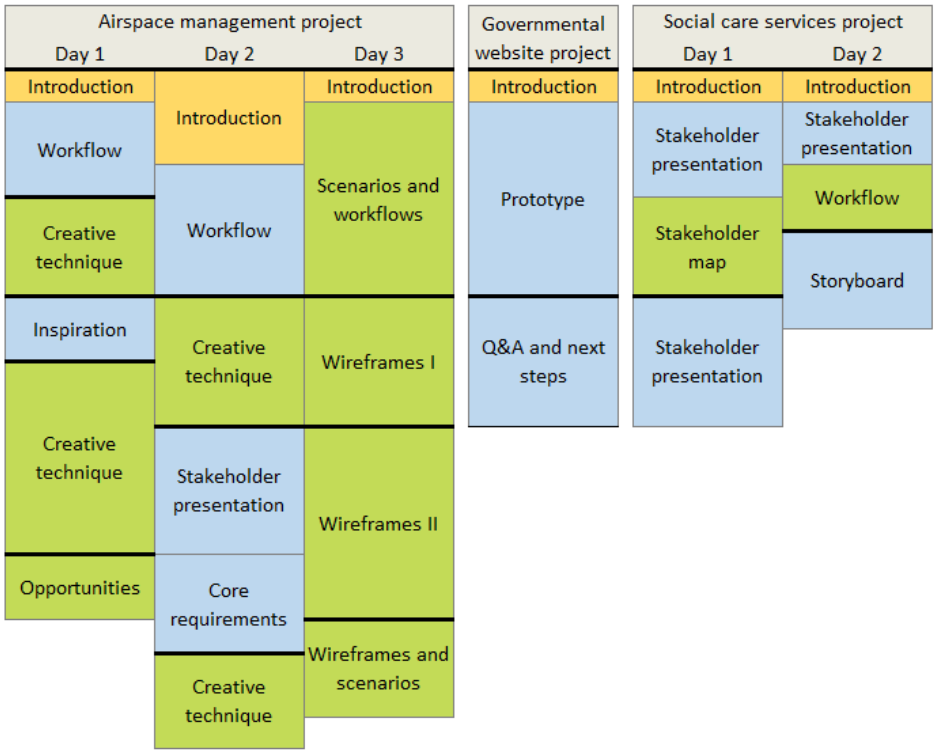

Figure 6. Outline of the agenda items of the observed meetings, including the following phases: *preparation* (black bold lines), *introduction* (yellow) and *design* (green - *artefacts as input* activities, and blue - *artefacts as output* activities).

3.4.1 Preparation Phase

The preparation phases involved the coordination activities that happened "behind the scenes", which had the purpose of managing the process and progress. During this phase, design teams coordinated and adjusted their tasks, team roles, and digital and material resources for subsequent or ongoing activities. One key characteristic of the preparation phase was that it revolved around internal coordination within design teams, without direct involvement of the external stakeholders. As illustrated in Figure 6, preparation activities took place throughout the meetings. The activities undertaken in this phase mostly involved the *arrangement of workspaces* and *division of team roles*.

The arrangement of workspaces included mostly mundane tasks to find the ideal setup to accommodate the stakeholders. For instance, design teams rearranged tables and chairs to optimize the physical space, and distributed the required stationary material (e.g., placing post-it notes and markers on tables, arranging whiteboards, and preparing handouts). The value of the preparation phase was taking care of mundane tasks before the start of the design activities, facilitating designers to focus their time and resources on the discussions. However, the arrangement of workspaces was not limited to menial tasks. It also included key tasks such as the fine-tuning of slides in anticipation of the meeting, and retrieving material to support the design activities (e.g., inspiration sources, and videos and reports containing previous design decisions).

The division of team roles involved coordination of the members of the design team to establish their responsibilities during the meeting. For instance, during preparation activities, the design teams agreed on “who does what” in consideration of the agenda for the meeting. The detected team roles were consistent with those described by Sonnenwald (1995). Lead designers prominently assumed the role of facilitating interactions, mediating conflicts, and ensuring that activity goals were met (“agent” role). Backing designers frequently assumed the role of documenting activities by taking notes (“gatekeeper” role). Both lead and backing designers took the “boundary translator” role, who explained the perspective of the design team to stakeholders.

Design teams organically switched between roles, and intentionally adapted when a lack of coordination was detected. This was a frequent occurrence during the three-day meeting for the *airspace management project*, mostly because the large number of attendees made communication and task division challenging. For instance, if a backing designer assumed the “agent” role to facilitate a discussion, and the topic started to diverge widely from that of the activity, the lead designer overtook the “agent” role. Furthermore, we detected an unspoken hierarchy within the roles assumed during the meeting. The backing designers seldom overtook the role of the lead designer. Conversely, if the lead designer overtook the role of the backing designer while facilitating an activity, the backing designer shifted his or her role to support the lead designer.

3.4.2 Introduction Phase

Design teams consistently started meetings with an introductory speech. The value of this introduction was essentially to clarify the current status and next steps of the project. Thus, introductions served to set a design mindset and to enable an initial common ground. The introduction briefed stakeholders about the details of the meeting (e.g., goals and agenda) and status of the project (e.g., timeline and milestones). This phase took place at the beginning of the session, and had an approximate duration between 15 and 30 minutes. These activities are marked in yellow in Figure 6. In addition, there was a brief introduction at the beginning of each design activity. These introductions gave an overview of the tasks to take place, clarified practical details (e.g., duration and organization), and made explicit the objectives of the activity, such as kind of information to be gathered and its scope. These introductions were not only useful on a practical level to coordinate the activities, but also helped to engage stakeholders into a "design mode", which was crucial to promote participation.

We exemplify this with a quote of the lead designer (LP1) of the *airspace management project* (day 3) while introducing the *scenarios and workflows* design activity: *"And there will be some give and take. We'll go back and forth, that's not a problem. That's OK. We're designing here, it's OK to make mistakes."* This utterance was useful to reassure and engage stakeholders to actively participate in the activity, without worrying about initial correctness of the scenarios. Furthermore, it was common for designers to rephrase the introduction speech in different ways in order to explain how to complete the activity in a way that is accessible for the stakeholders. This was the case in a conversation between the lead and backing designers (LP1 and BP1) and a stakeholder during the introduction phase of the same design activity:

> "LP1: *We're really interested in the user perspective. Try to document a normal day at work. Like annoying phone calls coming in. These kind of things interest us, because this is what will happen with [the system] in real life.*
> STAKEHOLDER: *Turn all this into plain text?*
> LP1: *In plain text*
> STAKEHOLDER: *The scenario… as a story…*
> LP1: *As you're about to go and make a film*
> BP1: *A script*
> LP1: *A script, exactly…"*

By using analogies to concepts that might be familiar to the stakeholders, the design team attempted to reach a common ground. In turn, introducing the activities carefully could result in more appropriate and useful outcomes of the activity. Notice in the quote above that the backing designer (BP1) supported the lead designer (LP1) in the "boundary translator" role to clarify what a scenario is in the scope of UCD, and that BP1's contribution was well-received by LP1.

3.4.3 Design Phase

Design activities were the heart of design meetings, as they contained the richest, and most relevant activities for both the design teams and stakeholders. These activities included discussions, some of which were steered with brainstorm techniques, to generate ideas, create sketches, and iterate artefacts such as storyboards, prototypes, and workflows. Preparation and introduction phases served to ensure that design activities ran as smoothly and productively as possible. The length of the design activities varied widely, with the shortest activities lasting approximately 30 minutes and the longest three hours. Figure 6 shows the approximate duration and topic/technique of each design activity.

We found interesting similarities in the introduction phase that characterized the transition to the design phase: *an artefact was the starting point for triggering the actual design activities*. In addition, despite the lack of a formal process, we found similarities between activities with regard to their goals, tasks, team roles, and outcomes. We can distinguish two groups of design activities: where artefacts are (1) the *input* for the activity and (2) the *output* of the activity. We elaborate on these types of design activities in the next sections using excerpts from the observed meetings.

3.5 Artefacts as Input for Design Activities

Design teams used artefacts as input to guide and facilitate discussions during the design activities. We label these moments as *Artefact as Input (A/I).* The goal of these activities was to disseminate and assess an existing design artefact. We detail the activities and artefacts involved in A/I activities in the sections below.

3.5.1 Artefacts Used During A/I Design Activities

Six out of eleven A/I activities included artefacts created by design teams before the meetings. These artefacts, which are traditionally associated with UCD processes, included lists of end-user requirements, workflows, and prototypes. During design meetings, design teams used both tangible and digital representations of these artefacts, such as slides, digital prototypes, and printouts. Figure 7 illustrates the storyboard activity of the *social care services project* (day 2).

Figure 7. Storyboard used as input for an A/I activity (*social care services project*, day 2).

The design team created this storyboard in anticipation of the meeting. This storyboard was used to illustrate a use case on how the future system could support potential end-users, such as patients and healthcare providers. During the meeting, the design team placed the storyboard in such a way that it was visible for all attendees. The lead designer (LP3) explained each scene, using gestures to signal where to look at. Thus, the storyboard became the focus of attention, which was pointed at, referred to, and iterated over by all participants.

Besides the artefacts created by the design teams such as the aforementioned storyboard, we observed four A/I activities which included the dissemination of artefacts made by stakeholders in preparation to the meeting. As stakeholders created these artefacts, their content was new for the design team. Thus, the design team focused on taking notes and synthesizing the information whenever

these activities took place. For instance, during the *airspace management project* (day 2), the design team listened closely to a presentation given by one of the stakeholders (see Figure 8). After the presentation, the design team organized an impromptu A/I design activity to synthesize the content of a presentation about the stakeholders' work practices. These activities are shown in Figure 6 (*stakeholder presentation* and *core requirements*).

Figure 8. Stakeholder giving a presentation, as designers listen closely in the back of the room during an A/I activity (*airspace management project*, day 2).

The outcome of the A/I activities is the information – gathered from stakeholders' feedback – required to iterate an artefact. This information is documented by the design team either directly in the artefact (see post-it notes in Figure 7) or in the form of private notes. Interactions were mostly passive, as teams focused more on communicating information than on discussing it. For instance, in the case of the activity depicted in Figure 8, the backing designers listened attentively to the presentation of the stakeholder, but whenever there were discussions, they remained silent. These discussions tended to include only the lead designer and the key decision-makers. The role of the lead designer was to keep the discussion within the scope of the design artefact, and to reach consensus about the next steps and priorities for the artefact and project.

3.5.2 Example of A/I Design Activities

We illustrate A/I activities, their goals, artefacts, and team roles with a representative activity that took place during the *governmental website project* (see Figure 6, *prototype*). Additionally, we reflect on the challenges encountered by the design team and their resolution.

Disseminating the Artefact and its Rationale

The A/I activity started as the lead designer (LP2) introduced the activity by explaining its objective, which was to present the results of an expert review of the existing website, and two prototypes that materialized design alternatives. Afterwards, the lead designer presented the usability issues found during the expert review. These issues were accompanied with screenshots of the website and evaluation criteria, such as design principles and usability heuristics. The evaluation criteria were referred to by LP2 as the "ground or game rules." The meeting attendees listened closely to the presentation of the lead designer, but only agreed or disagreed discreetly (e.g., nodding) or gave very limited remarks.

After introducing the usability issues and evaluation criteria, the lead designer presented two semi-functional prototypes with design alternatives. These solutions were first introduced in a verbal way, as the lead designer presented the rationale for each solution without showing the actual prototypes. Only the two key decision-makers from the stakeholders' team made comments during this presentation. Despite the lack of discussion, it was clear from the comments of these two stakeholders that following the rationale of the prototypes was difficult. Being aware of this situation, the lead designer reassured attendees that the solutions would become clearer once the prototypes were presented, as shown in the next quote by LP2: *"I'll show you what it looks like in a minute. Are there any questions now? […] This was the theoretical part, but I mean, this sets kind of... this frames the solutions that we came up with. We haven't just invented it, we've been thinking about it. And these are the reasons why we opted for certain directions."*

After explaining the rationale in a verbal way, the solutions were presented in a visual way using the prototypes. The lead designer used a walkthrough to present the possible interactions with the website. Additionally, he externalized the design rationale of the prototypes by presenting inspiration sources, such as other websites and previous decisions made in the scope of the project.

Assessing the Artefact with Feedback from Stakeholders

The feedback given by stakeholders regarding the prototypes was central to this activity. One of the challenges faced by the design team was to achieve a common

ground on the criteria to evaluate the prototypes. Regardless of the effort that was put into this, a common ground was not properly attained. We observed these efforts, for instance, as the design team struggled between guiding stakeholders to select the "most appropriate" solution based on relevant criteria, and giving them freedom to decide according to their own understanding of the design process. Figure 9 depicts this activity, with LP2 *pointing* to the prototype in order to show its different elements in a precise way.

Figure 9. Design activity where the designer points to a prototype in order to explain its different elements to the stakeholders (*governmental website project*).

The strategy used by the lead designer was reiterating the design rationale and process (e.g., alternatives, heuristics, and end-user considerations…). However, as the discussion digressed to topics less relevant for the artefacts (e.g., fuzzy organizational rules), LP2 prompted them to reflect on the issue and to keep the discussion for a future moment: "*But you can ask yourselves… do you need [certain element in the website]? Anyhow… I'm just provoking to help you understand why we came up with certain solutions."*

To keep track of the discussion, the backing designer (BP3) had the role of taking notes on a laptop. Thus, the ideas that the designer found important enough to record as future input for the artefact were not evident for the stakeholders. For instance, there were no corrections or amendments done directly to the prototypes. The lack of visual feedback made it difficult for stakeholders to grasp

the impact of the meeting's discussions and decisions on the artefact. In this way, the value of the A/I activity was to disseminate the design rationale for the prototypes and to gather the feedback required for their iteration. However, challenges emerged as feedback from the stakeholders was limited, and not all stakeholders found meaningful ways to contribute to this activity.

3.6 Artefacts as Output of Design Activities

A variety of artefacts were created as output of the discussions during design activities, which we label *Artefact as Output (A/O)* activities. These activities served to integrate the points of view of stakeholders and designers. A typical A/O activity involved a creative technique to collect and process the comments from stakeholders in order to be included in a design artefact. We detail the characteristics of A/O activities in the next sections.

3.6.1 Artefacts Used During A/O Design Activities

The design teams focused on gathering relevant information from stakeholders, as depicted in Figure 10. The comments from stakeholders were used as the basis for generating new artefacts, such as workflows, sketches, and mockups.

Figure 10. Creative technique to collect input from the stakeholders (*airspace management project*, day 1).

These artefacts ensured that a transition from a conceptual discussion to tangible results could be accomplished. Design teams actively facilitated and structured

A/O activities to cluster comments and resolve conflicting items. One of these activities, where the lead designer of the *airspace management project* collected the input from the stakeholders using post-it notes and categorized it into a whiteboard, is shown in Figure 10.

Design teams had to arrange the available workspace (e.g., whiteboard or flipchart paper) to facilitate the visualization of the evolving artefact and avoid cluttering. For instance, during the *social care services project* (day 1), the design team asked stakeholders to reflect on the beneficiaries of the system to create a *stakeholder map* (see Figure 6). The lead designer (LP3) collected the comments on post-it notes, and clustered them together with the stakeholders. However, one challenge was that the workspace was soon cluttered with many notes, which made it visualization of the evolution of the artefact difficult (see Figure 11).

Figure 11. Stakeholder map created during an A/O activity (*social care services project*, day 1).

To manage large amounts of information, the design teams used four basic actions to build artefacts. Designers *added* something to the shared workspace (e.g., a post-it note or a drawing), and *discussed* its content together with the stakeholders. As a result of this discussion, a new item was *created* (or an existing artefact amended), and/or an existing item was *moved or removed*. We

contextualize these basic actions with a representative example in the following section.

A positive aspect of A/O activities is that they enabled the creation of more inclusive artefacts, since all the stakeholders generated content to build the artefact. Stakeholders appreciated a direct link between their ideas and the evolving artefact. Thus, A/O activities can potentially lead to shared ownership of and accountability for the results of the design process. Conversely, the limitations of A/O activities were related to the fact that some participant(s) dominated the discussion and muted other opinions. Our observations showed that this often led to topic digressions, as stakeholders believed that the new topic was more relevant than the design activity at hand.

3.6.2 Example of A/O Design Activities

We discuss a representative example of A/O activities that occurred during the *airspace management project* (day 3) for the *scenarios and workflows* activity (see Figure 6).

Collecting Comments from Stakeholders

The activity started as stakeholders were divided in two sub-groups. They were instructed to create a scenario about future usage of the system using a pre-defined scenario template that captured information such as outline, goals, and setting of the scenario. The two backing designers were in charge of facilitating the activities for the sub-groups. We report on the activities of one of these sub-groups. The activity kicked off as the backing designer (BP2) restated the instructions for creating the scenario, and gave details on the information required to complete the pre-defined scenario template. The stakeholders were solely in charge of creating the scenario. The backing designer followed their discussion closely, asking questions to clarify the information that was unclear from her perspective, and prompting them to focus the conversation on the topic at hand. In parallel, the backing designer created post-it notes to reflect on potential “system screens” to realize the scenarios. Figure 12 illustrates this activity. These notes were kept private, and the designer iterated them throughout the discussion.

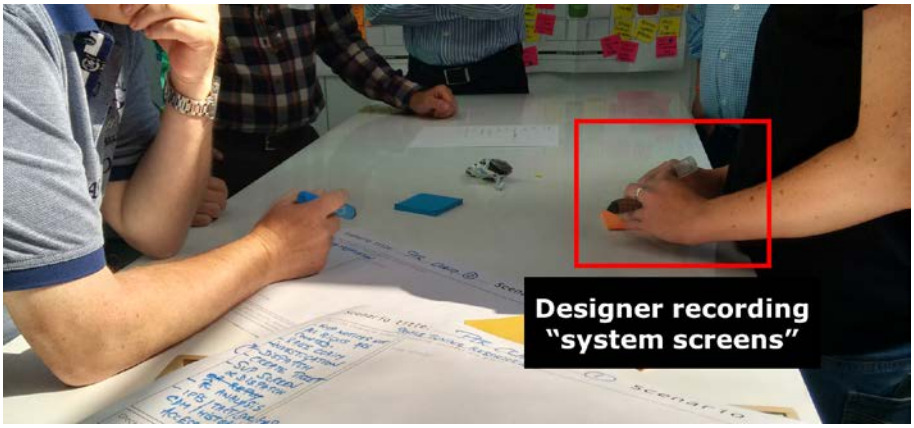

Figure 12. Backing designer creating "system screens" to record the discussion of stakeholders creating a scenario (*airspace management project*, day 3).

Processing, Integrating, and Revising Comments about the Artefact

After the group of stakeholders completed the scenarios, the backing designer explained the next steps of the activity. The designer invited the stakeholders to move to a nearby whiteboard to create a workflow using the system screens extracted from the scenarios (See Figure 13a). For each system screen, she explained what tasks it supported, and encouraged stakeholders to complement or correct the input. The backing designer used markers to add arrows to connect related screens, and annotated them with relevant information, such as user roles and tasks. The whiteboard turned into a "hotspot" where the stakeholders and the designers created the workflow collaboratively. Every time a post-it notes or element was added, the designer made a walkthrough of the workflow to make sure that the information is coherent and valid. This was done using her own words and understanding, as a way of appropriating the screen workflow to the design process. BP2 used utterances such as: *"As I understood, correct me if I'm wrong, [explanation of process]."* Translating the comments from stakeholders into the "design language" was important to prevent miscommunications.

Four basic actions enabled the designer to methodically revise all the collected comments and to process them in coordination with the stakeholders. The most recurrent actions were to discuss content to be included in the workflow and to create a new item (e.g., new post-it note or arrow to connect items).

(a)

(b)

(c)

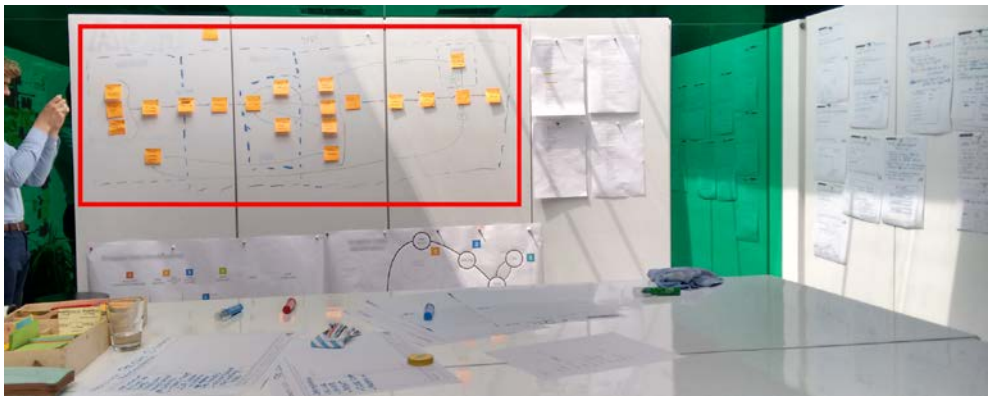

Figure 13. (a) Backing designer and stakeholders co-creating a workflow (framed in red) using (b) four basic actions. This A/O activity resulted in (c) a finalized workflow and wireframes (*airspace management project, day 3*).

In 14 instances, previously created content was added (e.g., post-it note created by the backing designer during the scenario). The least frequent actions were moving items to a different place in the artefact, with four occurrences (e.g., post-it note or arrow changed place), and removing content (e.g., discarded an idea

contained in a post-it note), with one occurrence. This activity lasted around 30 minutes, and is illustrated in Figure 13a.

These four basic actions we identified, shown in Figure 13b, reflect the fact that artefacts under construction are central to facilitate interactions. The backing designer made frequent walkthroughs through the workflow to make sure that the information was coherent and valid for stakeholders. The designer pushed to include all ideas, as during our observations only one single idea out of more than 25 was discarded immediately.

Updating for Completeness and Workspace Layout

Shortly after finalizing the workflow (see Figure 13a) the backing designer informed the lead designer (LP1) that the activity was concluded. The lead designer approached the whiteboard and gave stakeholders a print-out that reported on the concepts discussed and agreements reached during the previous two days (day 1 and 2 of the meeting).

The lead designer gave the stakeholders the task of ensuring that the information in the print-out was adequately reflected in the workflow. This strategy was used to ensure consistency and coherence with previous agreements, but also to enhance the accountability of stakeholders about their contributions to the process. However, we noticed that only two out of five stakeholders were actively involved in this task. We believe this was in part because the design team was not supervising or enforcing this task.

By the end of the activity, during the coffee break, the backing designer refined the layout in order to be presented to the rest of the stakeholders in its complete form and to serve as input for the next activities. The finalized workflow is presented in Figure 13c, in conjunction with other artefacts created during the three-day meeting. Thus, the value of the A/O activities was to create artefacts in collaboration with the stakeholders, in a way that reflected the opinions of a variety of team members in a visible way. However, these activities needed to be closely facilitated by the designers in order to keep the discussion in line with its objectives.

3.7 Design Directions to Support Interactions around Artefacts

In accordance with previous research, our findings revealed that design meetings are organized in a thorough way (Olson et al., 1992; Walz et al., 1993). Elements such as the included people, activities, and materials were not arbitrary, but rather planned to have an impact in the process. However, the dynamics of the meeting did not always occurred as anticipated. Consequently, design teams had to improvise and adapt quickly to resolve *unhelpful occurrences*, as they hindered the process from moving forward.

Design teams faced challenges related to practical aspects (time constrains, physical space), UCD approach (ill-defined problems, multidisciplinary), and tool support (technologies available). Artefacts were used to resolve some of these unforeseen occurrences, as they helped to focus the discussion. During meetings, artefacts were actively used to externalize knowledge in a visual way. This was useful to link different Communities of Practice and advance the shared goals of the Community of Interest.

In this section, we discuss how designers addressed unhelpful occurrences with the use of artefacts, both created *before* or *because* of group discussion (A/I and A/O respectively). We articulate the challenges found in the meetings together with the strategies used by design teams to resolve them, and reflect on the role of artefacts during design activities. Table 4 lists challenges that we repeatedly encountered during our observations. Furthermore, we synthesize a set of *design directions* – or design spaces to explore (Sengers & Gaver, 2006) – on organizing early stage design meetings, and reflecting on what kind of systems could support meetings in both co-located and remote settings.

We believe that these design directions can inspire technologies to support a variety of design activities with different levels of user involvement (e.g., from simply informative to participatory engagement with end-users). Furthermore, while they are inspired by co-located interactions, we believe they are flexible and high-level enough that can be useful to reflect on the possibilities of digital tools to support remote meetings.

Challenge	*Design direction*
Engaging diverse team members into design activities	Facilitate a shared workspace at all times
Considering multidisciplinary points of view	Include everyone during design meetings
Making decisions and sustaining them over time	Keep evolving artefacts visible and tangible

Table 4. Challenges and design directions to facilitate design activities during early stage design meetings.

3.7.1 Engage Diverse Team Members with a Shared Workspace

The observed design meetings involved actors from different Communities of Practice who strived to achieve shared goals. However, achieving these goals is not straightforward, as the different Communities of Practice had little to no knowledge about each other's domain. On the one hand, design teams invest time and resources – both before and during the meeting – to learn the domain of the project. Designers are usually proficient in this activity, being used to collaborating with people from different disciplines and having to adopt the vocabularies of a specific target domain in their projects. Stakeholders, on the other hand, are not necessarily active in learning about the design domain. During meetings, however, it is relevant for stakeholders to have an overview of the process to be able to contextualize design choices. For this reason, design meetings require *mutual learning*, as two (or more) Communities of Practice have to learn from each other to achieve shared goals. It is not only the designers who learn about their stakeholders, but their stakeholders also learn from the designers. Mutual learning has the potential to promote creativity and innovation by building on top of each other's ideas in a collaborative way (Fisher et al., 2005).

We found it was not always easy for stakeholders to engage in (often unfamiliar) design activities. For instance, for stakeholders it was not always clear what was the role of an artefact in the design process, how a scenario could be used to inform a high-fidelity prototype, or how a usability guideline was reflected in a design decision. One explanation for this lack of clarity from the point of view of

the stakeholders could be that designers were presenting *formalized documentation* during meetings, which made the rationale of artefacts opaque. For instance, during the A/I activity described in Section 3.5.2, the lead designer had problems explaining how certain guidelines informed their prototype, since the stakeholders could only see (and react on) a polished outcome. This would imply that the stakeholders could benefit from revisiting intermediate (and potentially more exploratory) versions of artefacts in order to contextualize them into the process.

Other reasons for this challenge include not only the lack of shared knowledge, but also the fact that stakeholders lack a way of "talking about design." This led to the following unhelpful occurrences due to a low level of engagement during design activities:

- Stakeholders do not fully understand the value/goal of a certain design activity, or were unable to follow the "train of thoughts" of designers;
- Limited remarks or feedback about artefacts, since it was not clear for stakeholders *where* or *how* to contribute; and
- Digressions, loud voices, and "separate" discussions.

A strategy to tackle these unhelpful occurrences was to communicate value by restating the *goals* of an activity and *clarifications* of design concepts. For this, designers relied on familiar examples and terminologies (e.g., describing a scenario as a script). To recover from digressions and loud voices, a strategy was to create "new" workspaces to cater these comments, but refocus the discussion on the goal of the activity at hand.

As previous research indicates, it is common that only a handful of attendees actively give input during early stage design meetings (Olson et al., 1992; Walz et al., 1993). A/O activities were useful to engage stakeholders to participate actively, as all stakeholders were required to provide input by following explicit instructions on how to contribute (e.g., create post-it notes). Furthermore, A/O activities have a strong visual component and take place in a shared, physical workspace which focuses attention on the artefact and its transformation. "Conceptual" workspaces (e.g., were no visual aids were used) were more complex for the stakeholders, and discussions were more limited. In this sense,

visual artefacts contained in shared workspaces are “emergent boundary objects” (Dalsgaard, Halskov, & Basballe, 2014), as they are used to focus the discussion with emphasis on its progression and dynamic transformation.

Design Direction #3

While design meetings are most often co-located, it is not always the case that all attendees share a workspace. We define a workspace as a physical (or digital) space that facilitates collaborators to work and focus on discussions (Dourish & Bellotti, 1992). During the preparation phase, design teams often craft their workspaces carefully around (sets of) artefacts, within a given physical infrastructure. *Before a design meeting starts, an initial shared workspace setting that is sufficiently flexible, yet contains the elementary artefacts, should be devised*. The introduction phase is used to situate stakeholders in this workspace. From then on, the challenge is to steer the team in maintaining a single shared workspace, so they have a common infrastructure that enables group communication and awareness. Workspaces observed during the meetings included one or more shared artefacts, such as workflows, templates, or storyboards (such as the ones depicted in Figure 7, Figure 9, and Figure 10) or a whole array of artefacts, such as those depicted in Figure 13c. In all these cases, the artefacts and spaces were used to focus discussion. Designers tend to coordinate their activities and make decisions on the spot as a reaction to various events that occur during the design meeting. A shared workspace provides a context for design decisions and mutual understanding.

3.7.2 Include Multidisciplinary Points of View during Design Meetings

We observed that interactions during the meetings were task-oriented and with a free flow of ideas. In UCD, having a multidisciplinary point of view can be used to promote inclusion, and to anticipate to different usage styles (ISO, 2010). During the meetings, however, a diversity of points of view often meant that there was a lack of common ground. Common ground is essential for communication and coordination (Clark & Brennan, 1991). Having radically different areas of expertise make it difficult to recognize the value in a discussion, as each Community of Practice has their own practices, terminologies, and goals. The unhelpful

occurrences that took place due to the variety of points of view and lack of common ground were:

- Unbalanced floor control (one point of view dominates the discussion);
- Design teams struggled to facilitate the activity and coordinate their roles (i.e., team was out of sync); and
- Internal issues from stakeholders who take over the design meeting (e.g., inclusion of "atypical" end-users, or interrupting the design meeting to discuss internal issues).

To tackle the occurrence of theseunhelpful occurrences, the design team used the preparation phase wisely, as designers coordinated their roles to facilitate communication. For instance, design teams encouraged the "expert" on each topic to take the floor (either a designer or a stakeholder). Furthermore, the introduction phase seeks to establish an initial understanding about the objectives of the design activities.

Artefacts were used to "negotiate boundaries" between Communities of Practice, as a way to include, compile, and structure different points of view (C. P. Lee, 2005). For instance, the stakeholders presented artefacts relevant for their practice, which were used as a reference for new, shared concepts and ideas together with the design team. These artefacts were not the ideas or design concepts themselves, but they were used to push the boundaries and communicate ideas to others. In this way, artefacts are boundary objects in the sense that are actively transformed and negotiated by designers and stakeholders during design meetings.

Design Direction #4

By situating all information in a shared workspace where design rationale and artefact evolution are visible, a team can strive to create shared common ground continuously. Tools for collaboration during early design activities need to mediate and manage the various contributions to facilitate *shared ownership*, *accountability*, and *balanced fairness* of what ends up in the design results. Conflicting points of view, and different opinions on what is important for evolving an artefact and for the design process (e.g., features to include or discard, and aesthetics to follow) surface much faster like this. Stakeholders can recognize

their input as part of the whole context, have a basis for common ground that enables a sensible and informed discussion, and link to their ideas with the resulting design artefacts. Having clear social cues on who contributed with what elements is easy in a face-to-face setting, but might be complex in a remotely. Thus, it is important to have a shared, digital workspace where the contributions of all team members can be integrated, and where discussions can have a strong visual component (e.g., centered on artefacts). Digital workspaces that enable artefact-based communication have proven to support creating a record of design work, which is useful to "reflect on and for team agreement" (Gutierrez Lopez et al. 2018).

3.7.3 Recording Decisions Using Visible and Tangible Artefacts

While the free flow of ideas during the discussions promotes creativity and tackles complex topics in a collaborative way, it can create traceability issues (Walz et al., 1993). Hence, it is relevant to document why certain alternatives were explored, discarded, or selected in the scope of the meetings. We observed that designers strived to progress the discussion to two points of resolution: (1) reach a decision (e.g., all people involved agree upon a course of action), or (2) fail to reach consensus, but agree upon how to achieve it in the future (e.g., who to involve or when to address the issue in future stages of the project). These decisions (or lack thereof) were often documented in artefacts (e.g., meeting minutes), or made explicit in an oral way by designers. The unhelpful occurrences related to reaching and documenting decisions were:

- Not all decision-makers are involved in the meeting, which means that designers need to justify *what* decisions were taken and *why*.
- The overwhelming amount of information that is processed during design activities made it difficult to record the context in which resolutions (decisions or otherwise) were achieved.

To overcome these unhelpful occurrences, design teams recorded the meetings and their outcomes meticulously, creating artefacts such as minutes, lists, reports, videos, and workflows. These artefacts represented the raw documentation created as a result of the meetings. A potential risk of documentation is that the design rationale attached to each item may be lost, as

ideas are extracted from a larger, more extensive conversation. For this reason, design teams invest time in coordinating their activities (e.g., during the preparation phase), often to assign a designer to the "gatekeeper" role to document discussions (Sonnenwald, 1995). In addition to the documentation generated during the meeting, the design team of the *airspace management project* mentioned creating a full transcript of the meetings in order to pinpoint where system requirements emerged.

We found that documentation was an integral part of the practices of designers, as they had defined ways of creating, storing, and disseminating their documentation. In this way, documentation is integrated into the larger infrastructure available for designers (e.g., at the design studio). As such, the documentation was embedded in an existing space (e.g., a shared repository). Part of the documentation was shared with stakeholders (e.g., via e-mail), while other information remained private to the design team.

Design Direction #5

Recording how artefacts came to be and what design decisions contributed to their current state is important. However, this might interrupt the creative flow, so *methods and tools for capturing the emergent design rationale should have a low threshold for usage and cause a minimum of friction*. Potential solutions are to use tangible versions of artefacts, and make design meetings as hands on as possible.

Simple yet effective formats to record design rationale can be useful. However, these formats should not enforce a particular structure in order to accommodate the different strategies of design teams and different types of design activities. We propose and trial one such format, the *Decision Cards*, in Chapter 5. These cards are lightweight formats that have been used in design workshops to capture artefacts and their rationale in a standardized way, but without influencing the process. Keeping decisions in a tangible and accessible way, both those taken during the meeting and beforehand, can facilitate making informed decisions for stakeholders.

3.8 Conclusion

In this chapter we investigated the role of artefacts to mediate collaboration during design meetings. We observed six design meetings involving professional, multidisciplinary design teams following a UCD approach. Consistent with previous research, we found that design meetings had similar phases, despite the lack of a formal process: *preparation*, *introduction*, and *design* phases. The design phase consisted of a variety of design activities such as brainstorming and sketching. The preparation and introduction phases ensured that these design activities ran as smoothly and productively as possible. Artefacts were used as starting points to trigger design activities, and in some cases, acted as boundary objects to mediate collaboration regardless of the lack of common ground. We contribute with a discussion on the challenges faced by designers during design meetings, and three design implications on how to cope with these challenges, as described below.

First, starting from the preparation of a design meeting, a single shared workspace should be offered, so all participants have a common infrastructure that enables group communication and raise awareness on the ongoing design activities, progress, and results. A shared workspace provides a context for design decisions and mutual understanding. Second, tools for collaboration during early design activities need to mediate and manage the various contributions to facilitate for shared ownership, team member accountability, and balanced fairness of what ends up in the design results. Finally, tools for capturing the design rationale should have a low threshold for usage, and cause a minimum of friction. Thus, these tools should enable capturing rationale without imposing a specific working style or interrupting the design process. These three design directions are based on observations of multidisciplinary design teams, and surface essential aspects to support during design meetings. While these directions are inspired by face-to-face engagements, we believe they could be equally useful to support remote meetings. We explore the practical applications of these design directions, in addition to those presented in Section 2.5, in order to create tools to support collaborative design within multidisciplinary teams in Part II of this dissertation, particularly with the Decision Cards reported in Chapter 5.

Part II: Approach to Documenting Design Rationale and Decisions

4 Helaba: A Tool for Recording Design Rationale

Design activities associated with the ideation phase of design processes require mutual understanding and clear communication based on artefacts. However, this is often a challenge for multidisciplinary teams due to the lack of ad hoc tools for this purpose. Our approach is to tackle these limitations with tools based on the design directions articulated in Part I of this dissertation. These design directions indicate that explicitly interconnecting artefacts with their rationale can help to support visual communication, and engage diverse team members in a shared workspace. Such workspaces should support designers to organize large amounts of information and maintain awareness of artefact evolution over time. In this chapter, we introduce *Helaba*, a prototype of a tool to create a shared workspace to support communication revolving around design artefacts and activities. Furthermore, we describe the design process and a preliminary evaluation of this tool. This research is partially based on the paper published by Gutierrez Lopez, Haesen, Luyten, & Coninx (2015a).

4.1 Introduction

Interaction design is a complex knowledge activity that more often than not involves multidisciplinary teams (Löwgren & Stolterman, 2004). These teams often lack the tools for efficient collaboration and communication, specifically because the different roles involved also have different work practices and domain specific languages (Rogers, 2004). Previous research indicates that designers consider team and stakeholder communication a key issue that influences the quality of their designs and design decisions (Eckert et al., 2005; Gutierrez Lopez et al., 2015b; Rogers, 2004). We aim to tackle these limitations by explicitly connecting pieces of information related to design rationale, feedback, and evolution with the artefacts that are subject of communication.

To this end, we propose *Helaba*, a prototype that creates a shared workspace around design artefacts with the aim to support multidisciplinary communication.

The word “helaba” is used in the Flemish spoken language to greet someone, but also to attract the explicit attention of another person and point something out[1]. Helaba focuses on documenting design rationale, low threshold decision-making, and multidisciplinary communication. Helaba helps to facilitate the team communication as well as documenting the rationale that led to certain design decisions. Our tool does not include artefact editing or manipulation and leaves this work to specialized design software. With this focus, Helaba ensures that different disciplines involved in design teams can adopt it without moving away from familiar tools.

In this chapter, we present related work relevant to our tool, followed by a detailed description of Helaba, including its design guidelines, usage scenarios, and formative evaluation. To conclude, we describe how this assessment served to iterate over the prototype.

4.2 Related Work

Communication during the early stages of design is often linked to visual artefacts (Eckert & Stacey, 2000; Sharmin & Bailey, 2011). However, existing systems tend to focus on the support for creating these artefacts, but not on the influence of communication to their evolution (Sharmin & Bailey, 2011). A potential approach for integrating communication and artefacts is by capturing the design rationale. As mentioned in the Introduction chapter, design rationale is a documentation of the reasons (or ideas) that shaped an artefact, and how its evolution is contextualized within the design process (Moran & Carroll, 1996). Similarly, MacLean, Young, Bellotti, & Moran (1991) argue that design rationale is a representation of the reasoning behind the design of an artefact, evolving with the design process by capturing design decisions and how they relate to relevant evaluation criteria. Thus, design rationale can be useful when artefacts need to be understood by many people, allowing them to better comprehend the design decisions of others (MacLean et al., 1991).

[1] https://en.wiktionary.org/wiki/helaba

In order for design rationale to be effective, it should reflect on the reasons (or arguments) behind each decision and alternative explored (Burge & Brown, 1998, 2000; J. Lee, 1997). Argumentative rationale is largely based on *IBIS* (Issue-Based Information Systems), a notation for political argumentation proposed by Kunz & Rittel (1970). This notation and its variants have been applied to systems emerging from the field of engineering design to capture design rationale. We will describe some of these systems in the section below. According to Shipman & McCall (1997), the goal of the argumentation perspective is to structure how designers *reason* about a problem and alternative solutions, expecting to *improve* the outcomes of the design process. Table 5 summarizes the characteristics of the argumentation perspective discussed in function of their goals, approaches, advantages, and limitations (Shipman & McCall 1997).

Argumentation perspective	
Goal	Structure the reasoning of designers, improving the outcomes of the decisions
Approach	Semi-structured notations which connect related ideas
Advantages	Retrieving and reusing rationale; communicating to externals; comprehensively recording ideas
Limitations	Capturing rationale is cumbersome since it imposes structure in the reasoning process; not widely adopted by designers

Table 5. Goals, approaches, advantages, and limitations of the argumentation perspective to capture design rationale (Shipman & McCall, 1997).

As mentioned before, an advantage of the argumentation perspective that is reported in literature is its potential of improving the outcomes of the design process by organizing the thinking process of designers (Shipman & McCall, 1997). According to Burge & Brown (2000), design rationale can create a “corporate memory”, where original ideas and intents are recorded. Such a record of ideas can help to avoid duplicating work, and considerably facilitate retrieving

decisions and their rationale (Burge & Brown, 2000; Shipman & McCall, 1997). In the sections below, we describe a number of semi-formal notations that have been proposed within the argumentation perspective, followed by a discussion on the pitfalls of these notations.

4.2.1 Approaches to Argumentative Design Rationale

Semi-formal notations (or languages) are used as approaches to represent design rationale, being mostly explored in the field of design engineering. Each approach uses unique elements and connections to represent rationale, but most of them are derived from the *IBIS notation* (Shipman & McCall, 1997). We created Figure 14 to visualize a basic, albeit simplified, structure of these elements and connections: a *design problem (or issue, question…)* is framed with potential *alternatives*. These alternatives are evaluated with relevant criteria (*pros and cons*). This evaluation (or argumentation), leads to claims to support why an alternative is ultimate accepted or rejected as a *solution*.

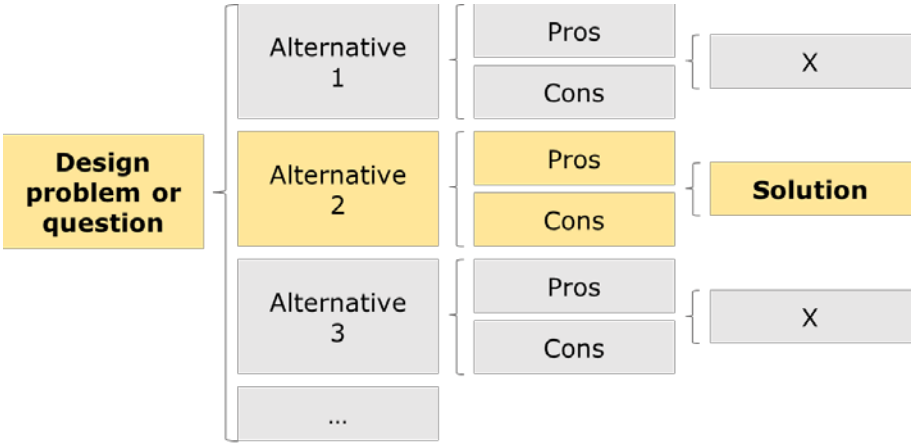

Figure 14. Basic model of the argumentative approaches to design rationale.

Given the extensive research about the argumentative perspective, we use it as a starting point to explore the type of information to be recorded in a design rationale tool. The information recorded to generate design argumentation is often visualized with specialized tools (mostly emerging from research) or simple diagrams (e.g., tree and flow diagrams, much like the model in Figure 14). These visualizations serve to represent the relation between different notation elements

and their connections. For example, in the case of the figure above, the nodes connect a design problem with alternative solutions, and the argumentation for accepting or rejecting them.Below we expand on the most relevant notations and tools of design argumentation, followed by a description of their core limitations and our approach.

IBIS notation

The IBIS notation represents design problems, their alternative solutions, and related tradeoffs. This notation helps to create "issue maps" (Kunz & Rittel, 1970) to ensure that design is consistent and complete. The IBIS notation is represented graphically in *gIBIS* (graphical IBIS) and *itIBIS* (textual IBIS) (Conklin & Burgess Yakemovic, 1991). Likewise, *Compendium* is an IBIS-based environment to structure rationale with hypermedia elements (Shum et al., 2006).

PHI notation

The *PHI* (Procedural Hierarchy of Issues) is a variant of the IBIS notation which helps to structure and formalize information in an incremental way (Shipman & McCall, 1997). It extends from IBIS by promoting the reuse of previously-captured information. Systems that use the PHI notation include: *PHIDIAS* (McCall et al., 1990), which combines CAD designs, multimedia, and argumentation; and *HOS* (Shipman & McCall, 1997), that integrates and formalizes textual information (e.g., e-mail and notes) to support design communication and progress.

Design Space Analysis

The *Design Space Analysis* (DSA), proposed by MacLean et al. (1991), uses the *QOC* (Questions, Options, and Criteria) notation to represent the questions around an artefact, the options to solve these questions, and the criteria for assessing the option. The *TEAM* notation extends on QOC, and is applied in the *DREAM* tool to enable traceability and rationalization during the engineering design of interactive systems (Lacaze & Palanque, 2007).

Decision Representation Language

Decision Representation Language (DRL) (J. Lee, 1989) is a notation to represent decision-making processes based on argumentation. This language connects and

establishes dependencies between *alternatives,* which are evaluated against *goals* and relevant *claims.* DRL expands IBIS by including the concept of goals. *SIBYL* (J. Lee, 1990) is a tool that uses DRL to visualize and share knowledge acquired during the decision-making process. *InfoRat* (Burge & Brown, 2000) uses DRL to map design phases to their goals and associated alternatives, using rationale to ensure that the alternatives are consistent with the goals.

4.2.2 Our Approach to Argumentative Design Rationale

While these tools and notations offer a valuable insight into how to facilitate the decision-making process and to exchange information to reach consensus, their adoption among professional designers is limited (Burge, 2008; Shipman & McCall, 1997). The core reason why these notations are not adopted on a large scale is because they impose a structure in the design thinking, which is inconvenient for designers (Horner & Atwood, 2006). Furthermore, if documenting design rationale is not integrated into the design process, it can become a barrier for its progression (Burge & Brown, 2000; J. Lee, 1997). For instance, the IBIS notation can help to structure rationale on a small scale (e.g., meeting notes), but it can be problematic for a full process (Burge & Brown, 1998; Conklin & Burgess Yakemovic, 1991).

We situate our research in the scope of argumentative design rationale to define the type of design information to capture, but aiming to minimize the limitations related to structuring the full process. More specifically, we use the QOC notation (MacLean et al., 1991) as inspiration for features to capture design rationale information. We adopt the QOC notation since it is intended to be accessible and easy to understand for team members from different disciplines (Lacaze & Palanque, 2007; MacLean et al., 1991). Our initial approach, which we investigated using the first prototype of Helaba, focused on creating a space for capturing the *questions* around an artefact, the *options* (or conversations) to answer them, and the associated *evaluation criteria*. Nevertheless, we sought to avoid imposing rules about the amount or level of detail of the captured information. The sections below explain Helaba in detail, giving details about the design process and guidelines used to create it.

4.3 Creating Helaba: Design Process and Guidelines

We introduce *Helaba*, a tool to support communication revolving around design artefacts and activities within multidisciplinary design teams. A shared workspace that structures and tracks artefacts and communication is the main component. Thus, it can be suitable for both co-located and remote settings.

As will be detailed in the sections below, we created two prototypes of Helaba. The *first prototype* explores our initial ideas and concepts to support the documentation of design rationale. The *second prototype* is an iteration of these concepts, focusing on balancing engineering and creative approaches to design documentation. The underpinnings of both prototypes of Helaba is the knowledge gained during the user studies (Part I of this dissertation), active engagements with designers in order to assess these prototypes (Parts II and III), and literature reviewed throughout this PhD. The core contrast between these prototypes is that the first prototype represents rough ideas and concepts, while the second prototype represents a more mature solution.

4.3.1 Overview of the Design Process

As mentioned in the Introduction chapter, this PhD followed an overarching UCD approach to guide the design work. Similarly, we followed an iterative user-centered design process to create and iterate Helaba (see Figure 15).

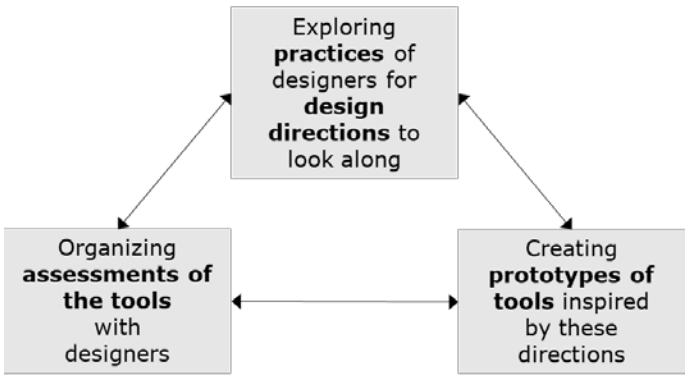

Figure 15. Overview of the activities we followed to create Helaba, where the arrows indicate an iterative process.

More than fixed or linear phases, the blocks in Figure 15 serve to illustrate that knowledge emerged from all activities, and accumulated along the process. In practice, these activities overlapped and interwove with each other. A critical reflection of this process is presented in Chapter 8 (Section 8.3.1). Below we describe; the activities we followed to create Helaba, and how they are informed by other activities conducted in the scope of this dissertation.

- **Exploring practices of designers:** These activities were targeted to investigating the collaborative practices of designers in order to identify the bottlenecks that could be better supported by technology. These explorations are reported in Chapters 2 and 3, and pinpoint five design directions to look along for potential design solutions (Sections 2.5 and 3.7). Additionally, three concrete design guidelines extracted from these design directions were used to guide the design work of Helaba (see Section 4.3.2).
- **Creating prototypes of tools:** The *first prototype of Helaba* was used to explore the initial concepts and ideas, including notions of design rationale. The initial assessment of this prototype led to accepting and discarding some of its concepts, as will be described in Sections 4.4 and 4.5. The *second prototype of Helaba* was inspired by the first prototype, but was significantly reworked, extended, and inspired by further user studies and explorations with design teams. Notably, the second version of Helaba, which will be described in Section 4.6, integrated the Decision Cards, and was developed into a functional prototype.
- **Organizing assessment of tools:** We assessed Helaba at different stages of the process, in order to refine it with the input of design practitioners. These assessments were conducted at different stages of the process, and using different techniques. Each engagement with designers led us to a better understanding on how to contextualize these tools into collaborative design practices, and served to iterate our solution.

4.3.2 Design Guidelines of Helaba

We defined three *design guidelines* as concrete design rules for Helaba. These guidelines were inspired by the design directions contained in Section 2.5 and Section 3.7, which gave us a high-level overview of user needs emerging from

our studies with designers. More specifically, these design directions highlighted the need for tools to capture, structure, and present communication within multidisciplinary design teams. We grouped, refined, and specified these design directions in order to inform the creation of Helaba with the following guidelines:

- **Design Guideline 1:** When multidisciplinary design teams communicate, there should exist a *connection between the tools for sharing artefacts and for communicating design rationale* to facilitate the creation of a common visual vocabulary.
- **Design Guideline 2:** When designers share and receive feedback from their team or stakeholders, there should exist a *shared workspace to capture and overview different points of view* in a centralized way.
- **Design Guideline 3:** When involved in artefact-based communication, design teams need to *gain awareness of the evolution of the artefact by having an overview of the process that was followed* (e.g., milestones and team involved) *and previous design decisions.*

These guidelines were refined throughout this PhD, as our understanding of the problem and solution grew together with user studies and explorations.

4.4 First Prototype of Helaba

An overview of the workspace of the first prototype of Helaba is shown in Figure 16, which represents the concepts behind our tool. The concepts included in this prototype were largely inspired by the user study reported in Section 2.3, as these were the starting points of my PhD research work (see Figure 1). This non-interactive prototype was created using Illustrator. The images of avatars, information, and the sketches in Figure 16 are examples used for illustrative purposes, but should not be considered as part of the prototype.

Three different types of information, each dealing with a design guideline, are useful to contextualize the content captured and presented by Helaba. *Rationale information* (Figure 16a) creates a visual link between artefacts and ideas behind them. *Feedback information* (Figure 16b) organizes and facilitates team discussions based on relevant criteria. *Evolution information* (Figure 16c) gives an overview of previous outcomes of the design process.

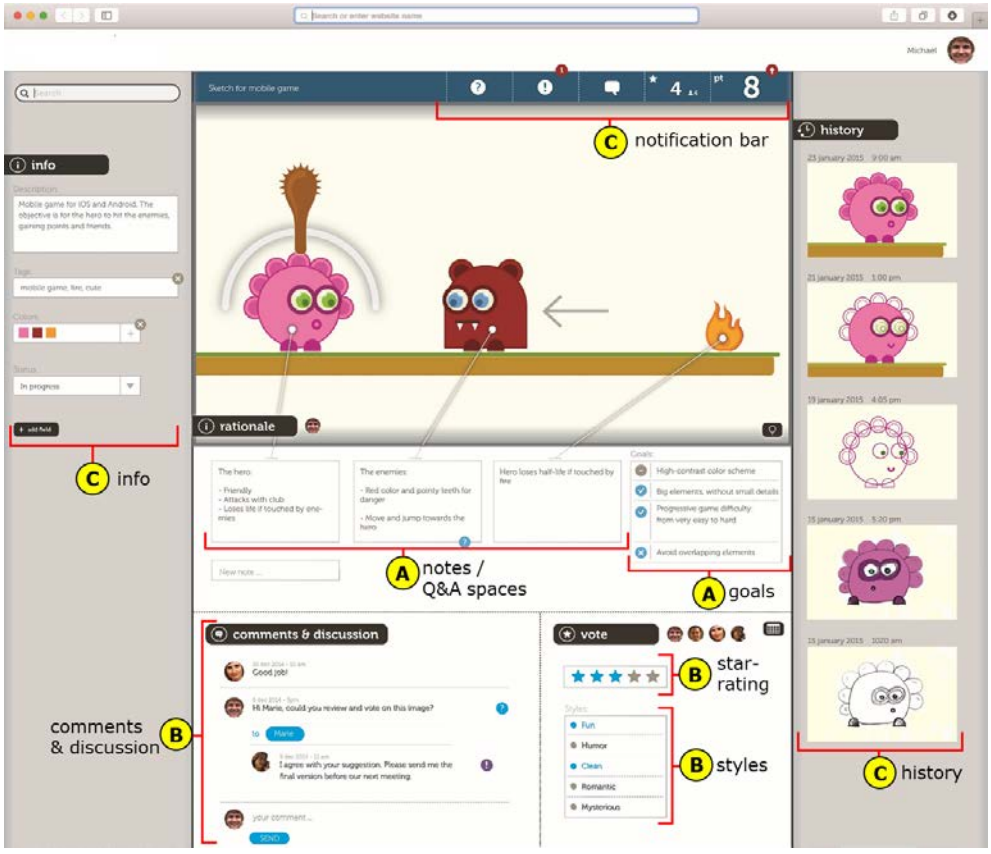

Figure 16. Overview of Helaba, including the three types of information: (a) rationale, (b) feedback, and (c) evolution.

In the next section, we describe three usage scenarios of the first prototype of Helaba, which are used to *illustrate its functionalities and reflect on potential applications and uses of our tool* in the context of design activities.

4.4.1 Reflecting with Usage Scenarios

The purpose of these usage scenarios is to present snippets of design practices, and to envision how they could be supported by the first prototype of Helaba. The scenarios were not the basis of the design work of Helaba, but were used to *reflect on its applications and refine its functionalities*. Hence, these scenarios are complementary to the learnings from the user studies reported in Part I of this dissertation.

These scenarios are inspired by observations conducted during the early stages of an interaction design project involving a multidisciplinary team. We created three open-ended, fragmentary narrative scenarios that exemplify communication activities and reflect on the pitfalls that are faced by designers. Following the suggestions of Bødker (2000), more than realistic scenarios, these are a *caricature* of the interactions observed in order to clearly appreciate their impact and consequences. The observed project involved six organizations from both industrial and academic fields, distributed across different locations in Europe. The team, formed by 11 professionals, worked towards the common goal of creating a shared UI design for an interactive system. The two reasons to observe this particular team and project are: (1) the involvement of geographically distributed team members with a diversity of disciplines, and (2) the high complexity of the design and technological problems that needed a solution.

It should be noted that the author of this dissertation was a team member of this project. Therefore, these observations recapitulate her experiences, reflecting on the challenges faced by the interaction designers involved in this project. In contrast with the formal user studies with designers reported in Part I of this dissertation, in the present study we did not use a full qualitative data analysis technique to generate findings. Nevertheless, the data here described was meticulously collected, as notes were generated for the specific purpose of generating these scenarios. As a result, these observations provided us with further evidence to describe design activities involving multidisciplinary teams. As the observed team and project were real, we protect their anonymity by generating a fictional design team for the scenarios. The (fictional) team consists of four key actors: *Joe* an interaction designer, *Pam* a visual designer, *Ann* a software developer, and *Danny* the project manager. We devote the next sections to describe these scenarios and their associated pitfalls, and to contextualize them with the design guidelines and types of information supported by Helaba.

4.4.2 Usage Scenarios, Pitfalls, and Helaba Features

Scenario 1: Transitioning from Individual to Team Work

As indicated in design guideline 1, when multidisciplinary design teams communicate, a connection should exist between the tools for sharing artefacts

and for communicating design rationale. As illustrated below, during the observations we identified a reoccurring situation where designers had issues to communicate the outcomes of individual design activities to a wider audience.

> *Joe, the interaction designer, had the task to individually create early UI mock-ups. He started by gathering inspiration and making some sketches to represent his ideas. Joe selected a few of these ideas and refined them further. Then, he used Illustrator to create a more polished version. He worked at ease, but lost track of the initial sources of inspiration and rationale behind his ideas. Thus, when presenting the work to the other team members, he had to come up with an explanation that had little resemblance to the original ideas and their evolution.*

Joe fell in what we call the *scattered rationale pitfall*, as he does not have a centralized record of how his design came to be. Designers invest much of their time and efforts working individually on their designs, but not on documenting the reasoning behind artefacts (Reeves & Shipman, 1992). This can create difficulties when transitioning from individual to group work, which involves struggles to communicate design decisions in a way that expresses their actual inspiration (Eckert & Stacey, 2000).

The rationale information recorded in Helaba can tackle this pitfall by creating a link between artefacts and the ideas behind the design choices in a visual way. As mentioned before, we used the QOC notation (MacLean et al., 1991) as inspiration. In Helaba, rationale information links a visual artefact (e.g., sketch, static prototype, or storyboard) to the *questions* that emerged during its creation, the different *options* explored, and the *criteria* that guided its evaluation. Three features are included to capture rationale information: Notes, Q&A spaces, and Goals, as illustrated in Figure 17.

The *Notes* are *digital post-it notes* that can be used to include textual notes, and to pinpoint specific elements of the design. Users can transform individual Notes into a *Q&A Space* for discussing topics or asking clarification to specific team members. The Notes and Q&A spaces represent the “Options” and “Questions” of the QOC notation respectively. The *Goals* feature allows the creation of a customizable checklist containing design guidelines or requirements that serve as criteria for evaluating an artefact. Goals represent the “Criteria” of the QOC notation, as it is meant to include guidelines to evaluate the artefact. Items of the

customizable checklist can be marked once they are handled in the artefact, for instance, to establish it as accomplished (i.e., tick) or unaccomplished (i.e., cross).

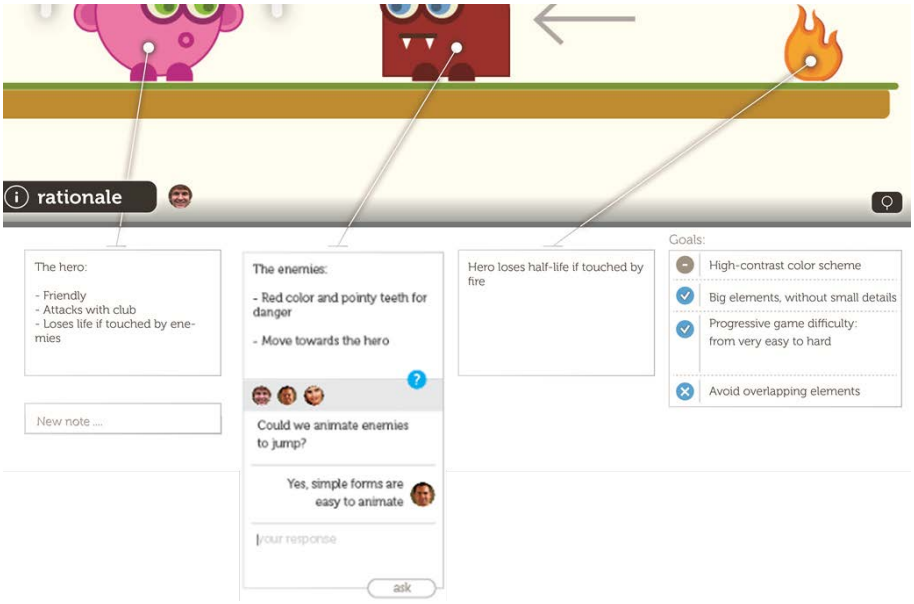

Figure 17. Notes feature with active Q&A space and goals feature with checked items.

Scenario 2: Integrating Feedback from Different Team Members

Design guideline 2 points out that when designers share and receive feedback from their stakeholders, there should be a *workspace to trace back the design decisions and rationale*. The scenario below describes one of the situations that commonly occurred while giving and receiving feedback in remote settings.

> *Joe organized a VoIP call with Pam and Ann to gather feedback about his UI designs in a remote way. During the call, Joe shared his screen to show the artefacts to his team, and explained how he envisioned the UI could work with his design. Pam and Ann listened to Joe's presentation carefully. Ann, a software developer, felt it was not the right time for asking questions relating to the implementation. Pam, a graphic designer, felt her ideas were not valuable enough to interrupt Joe's speech. The outcomes of this meeting were poor for the participants. From Joe's perspective, he did not gather enough feedback. From Ann's and Pam's perspective, they were not able to express their ideas and concerns in full, due to the limitations of communicating remotely.*

In multidisciplinary teams, designers must consider feedback from a variety of perspectives (MacLean et al., 1991; Reeves & Shipman, 1992; Sharmin & Bailey, 2011). However, remote feedback often implies a reduction of communication cues and a loss of human and work context, which makes it difficult to assess the reactions of others (Dourish & Bellotti, 1992). Therefore, the team fell in what we call the *incomplete feedback pitfall*, as they lost relevant information due to the limitations of the communication channel. Helaba overcomes this pitfall by integrating and facilitating the capture of *feedback information*. This information aims to organize general discussions and gather qualitative and quantitative feedback in an intuitive way. As shown in Figure 18, the features that support these type of information are *Comments & discussion* and *Vote*.

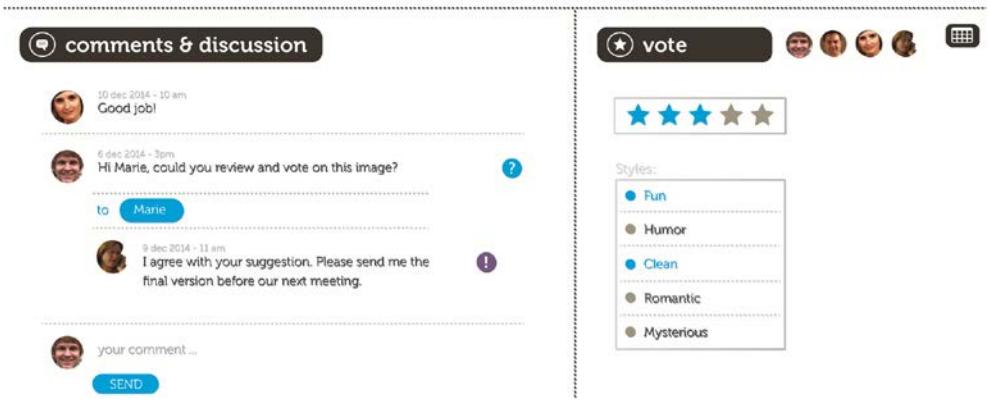

Figure 18. Left side: *comments & discussion* feature with comments marked as question or attention. Right side: *vote* feature with *star-rating scale* and *styles* suggestions.

The *Comments & discussion* feature is a space for team members to add general remarks about the artefact. Any comment can be marked to direct an inquiry (with a question mark) or to attract the attention (exclamation mark) of a specific team member. The *Vote* feature is a space to express impressions of an artefact in a quick, visual way using two options. The first option is a 5-points star-rating that provides an easy and intuitive way to express the perceived quality of a design. The second option is a list of user-defined categories (or *styles*) that are intended to capture how others perceive an artefact.

Scenario 3: Tracking Artefact Evolution

Design guideline 3 specifies that when involved in artefact-based communication, design teams need to *gain awareness over the evolution of the artefact*, having an overview of the process and previous design decisions. In our observations, it was relevant that not all team members were involved in the same way in all activities or stages of the process, as narrated in the scenario below.

> *Joe, Pam, Ann, and Danny gathered for a co-located workshop. Since Danny, the project manager, was not involved in the meetings to discuss the UI designs, he had several remarks about Joe's solution. This meant that Joe had to explain once more the rationale of his design choices, and that several points of view had to be considered. Not having a clear focus, the team discussion started to circle around previously agreed design decisions. This was a critical point of the project, as it could lead to wasting valuable ideas or resources.*

Danny fell in the *multidisciplinary decision-makers pitfall,* as he was not informed on how to proceed due to misinformation and unawareness of the process. This has the potential risk of having to dismiss novel ideas in favor of more traditional ones, which are easier to interpret for stakeholders (Eckert & Stacey, 2000). As design decisions evolve over time, stakeholders, both internal and external, could benefit of being informed about decisions in which they were not involved, or be reminded of past decisions (MacLean et al., 1991). The *evolution information* kept by Helaba is useful to overcome this pitfall. This information (Figure 16c) concerns the metadata of the artefact and timeline for traceability of its evolution, and is supported by the *History* and *Notifications* features.

The History is a timeline to record the evolution of an artefact's elements in chronological order. The Notifications provide an overview of the activities that took place on the artefact and who was involved with an activity feed. Additionally, the notification bar includes general information related to the acceptance rate and adherence to requirements, calculated with the Votes and Goals features respectively.

4.5 Early Evaluation of Helaba with Designers

We conducted a *formative evaluation* to assess the first prototype of Helaba using a paper version of the prototype depicted in Figure 16. Formative evaluations are useful to ensure that the proposed solution meets the intended requirements and

expectations (Rogers et al., 2011). Our goal was to assess if our solution fitted the design guidelines of Helaba defined in Section 4.3.2, and most important, if it was in line with expectations of designers. With this evaluation, we discovered opportunities for iterating our design proposal.

4.5.1 Methodology and Participants

The objective of this preliminary user test was to evaluate the functionalities of Helaba together with design practitioners. For this end, we used a paper version of the Helaba prototype, in combination with a set of scenarios in order to explore its core features. Paper prototypes are useful for gathering early feedback since participants perceive them as “unfinished”, thus open for discussion and improvement (Warfel, 2009). Each of the seven scenarios contained around five simple tasks that concerned a set of features and interactions with the prototype (e.g., add a note and mark it as a question). The facilitator of the session narrated the scenario and simultaneously simulated interactions using the paper prototype, adding cutouts to show (or hide) information.

Four design practitioners (1 female, 3 male) participated in this study (DP1 – DP4). The participants’ experience ranged between 5 and 12 years practicing one or more design disciplines, including interaction, graphic, industrial, and game design. All participants had previous experience working in commercial settings and collaborating within multidisciplinary teams.

The study was set up using a semi-structured protocol including scenarios that reimagined how current design practices could be supported by Helaba. As suggested by Bødker (2000), we used this technique to provoke ideas and envision future situations relevant for the participants. Each session lasted around 60 minutes, including an introduction to the study, the scenario walkthrough, and a post-test interview to explore in detail the opinions of participants. We prompted participants to express how the presented prototype was applicable to their design practices and to give critical feedback on its different aspects. Figure 19 depicts the setup of the study. Each session was audio recorded, and we also took photographs and notes to document the comments of the volunteers. Afterwards, the audio recording was partially transcribed and processed to search for recurrent topics and comments.

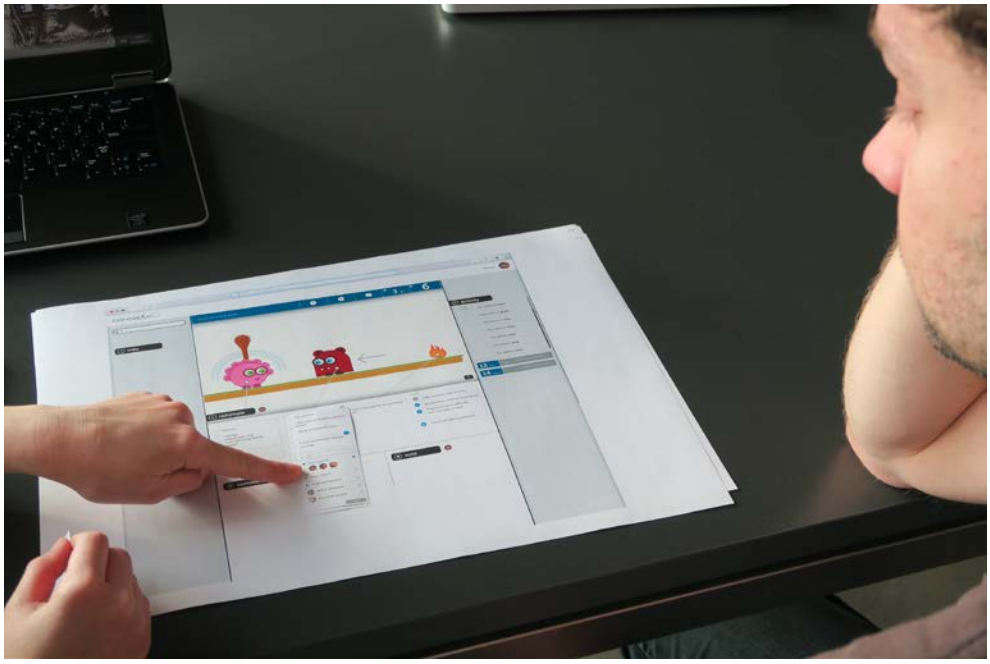

Figure 19. Setup of preliminary user test with designers and Helaba.

In the next sections, we report the results of this user test, illustrated with quotes from the participants involved.

4.5.2 Results

All participants found Helaba useful for commenting on artefacts and organizing feedback. Each participant had a different idea on how its functionalities could be useful to their own work. Next, we present the main findings of this evaluation according to the design guidelines that guided our design proposal.

Connect Artefacts and Rationale Information

In agreement with the results of the user study reported in Section 2.3, all participants mentioned regularly sharing artefacts and their rationale both to internal and external stakeholders (e.g., project managers, clients, and end-users). Their preferred way of communication was face-to-face with co-located team members. However, when face-to-face interactions were not possible, participants mentioned a number of workarounds. One strategy was to write the rationale, posting it into e-mails or Basecamp, and embedding the artefact.

Another strategy involved low-tech approaches, such as making printouts to add comments, or making phone calls to the client to explain an artefact. Participants mentioned these workarounds as inefficient, as they invest plenty of time and resources on writing the rationale, but it is often misinterpreted since the rationale is detached from the artefact. This finding mirrors the *scattered rationale pitfall,* described in the first usage scenario of Helaba (see Section 4.4.2).

Helaba creates a centralized workspace to link design rationale and artefacts, potentially allowing designers to create documentation in a way that can be shared directly with team members. Currently, rationale information is dispersed and it is often hard to connect it to design artefacts, as designers have no explicit tool for storing and sharing it. Helaba could solve this issue as illustrated by DP1, a graphic designer: *"[The Notes feature is]… very useful to connect to the part I'm talking about. Now I just type long e-mails, or a document with all comments, and they [team members] have to search what I am talking about. I would use it a lot."*

The Goals feature was considered to be useful for practical purposes, such as creating to-do lists or as a set of guidelines for project managers or clients to evaluate an image, as described by DP1: *"A lot of my clients have difficulties giving feedback because they don't know how to talk about design. […] Sometimes you get really strange feedback, but the clients could see it more as a goal achieved."* All participants expected the functionality of this feature to expand, for instance, to add textual comments on each element, and to pinpoint them to the artefact. This reflects the importance of contextualizing the results with the artefact.

Provide Feedback in a Shared Space

Participants reported that strategies for gathering feedback within distributed teams include using video conferencing and screen sharing tools for organizing remote, synchronous meetings. This strategy was as also reported in Section 2.3.3. The risk is failing to include a variety of points of view due to the technical limitations of this setting. This is the so-called *incomplete feedback pitfall* detected in the second usage scenario of Helaba. To avoid this situation, Helaba creates an open, shared workspace where designers and team members can participate in

discussions about design decisions in relation to evolving design artefacts. All participants found it important to know what their coworkers and stakeholders think, in order to be able to iterate their designs. It is not the evaluation itself, *but the reasons why a certain evaluation was given* that was particularly important for them. Thus, it is relevant that our prototype allows them to gather this information in an easy way.

The use of quantitative feedback (i.e., 5-points star-rating feature) in the Vote section was controversial, as its acceptance depended on the focus of the participant. The two participants who followed a commercially oriented design process described these features as highly desirable, as a neutral way of communicating and sharing feedback to their team and clients. In contrast, the two participants who usually followed an art oriented design processes would discard the quantitative feedback features (e.g., star-rating system). They mentioned that these features do not fit the paradigm of collaborative design at all, as quoted by DP2, a social designer: *"In the [design] process, I don't believe in numbers."*

When it comes to qualitative feedback (i.e., Styles feature of Helaba), all participants agreed that this is a valuable feature for evaluating images. DP3, a game designer, illustrates this: *"At first I thought [the styles feature] was a whimsical thing […], but it can be used if you want to achieve certain values on your picture… it's a good way to measure people's emotions when they see something."* The divided opinions about the Vote features make it evident that design practitioners use multiple approaches within the design process, depending on the nature of the project and the person they are interacting with. Therefore, it is vital to reflect on this flexibility by allowing designers to customize the features.

Overview Artefact Evolution

Design decisions are communicated to stakeholders, such as project managers or clients, who often do not have a design background. These situations might lead to the *multidisciplinary decision-makers pitfall,* as illustrated in the third usage scenario of Helaba. We envision Helaba could be useful for stakeholders to become

aware of the evolution of designs, the efforts invested in the design process, and other design choices that were explored but not implemented.

Participants focused on knowing *who said what* and *who was involved* in decisions in order to overview artefact evolution. This has the benefit of smoothening possible miscommunications that occur during the process, as illustrated by DP4, a graphic designer and illustrator: *"[Design processes are] not always friendly in real life, and it's good to keep track of who said what. This is done now by e-mail, but I like [about Helaba] that I can point out [in the artefact]."* Furthermore, participants were interested in having an overview of decisions and artefacts, as well as having a way to sort and archive artefacts in an intuitive way. This can give teams a better impression of how individual artefacts fit into the overall process, as described by DP2: "*In design it is not important the image itself, but how feedback on that image can inspire future steps and the process."*

4.5.3 Opportunities to Improve Helaba

The work presented has a set of limitations. First, our prototype was assessed with a limited number of design practitioners. Moreover, the scenarios we used to illustrate how we can support design teams only covered a limited number of situations. Despite these limitations, the formative evaluation demonstrated three promising opportunities for iterating Helaba: *simplify interactions*, *organize and overview artefacts*, and *open a dedicated space for design decisions*.

Simplify Communication

The first opportunity for iterating Helaba was to simplify the interactions whenever possible. For instance, having a complex procedure for requesting clients' feedback would result in less adoption, given the variety of practices followed by designers. Thus, the interactions in Helaba should be simplified to their basic form. As a result, we decided to unify the *Notes* and *Comments and discussion* features in order to contextualize all annotations and conversations together with the artefact. Furthermore, the *Evaluation* section should be simplified into one single feature for gathering feedback in the form of customizable polls. In this way, designers can define the type of feedback they want to gather, without a particular format or structure.

Organize and Overview Artefacts

Reflecting on the results of the user study conducted with the first prototype of Helaba, we found that it is not sufficient to keep a linear track of the history of design artefacts or a record of design rationale. Designers want to be able to build their own story of the design process. Further investigations should be directed toward exploring the navigation across different versions of an artefact. This includes extending the *History* feature to provide teams with a "big picture" of design processes without being overwhelming. The initial approach to support overview artefacts needs to be extended to also show how they are organized and stored. Furthermore, the *Notifications* feature should also be simplified to avoid imposing a way of overviewing design activities, as it might lead to misunderstandings.

Open a Dedicated Space for Decisions

Design teams invest plenty of effort and resources in recording design decisions as formally as possible in order to be shared with internal and external stakeholders. In the first prototype of Helaba, we included a feature to flag comments as *attention* or *questions*. The intention of this feature was to signal the important content in order to be evident to others. However, it could still be cumbersome to keep track or overview those flags over time, and the meaning or relevance could be unclear for people not familiar with the system. Thus, a space where decisions are easily accessible is required.

4.6 Second Prototype of Helaba

As mentioned in Section 4.3, our experiences and knowledge gathered with the first prototype of Helaba were used to inform a second prototype. We consider it as a second prototype because some ideas changed in a radical way: (1) discarding the idea of using a QOC notation, (2) retaining but simplifying the core features (e.g., shared workspace, Notes, and conversation spaces), and (3) including Decision Cards as a space for recording design decisions (see Chapter 5). However, we still call it "Helaba" as it retains the same underlying features, principles and guidelines, albeit implemented in a more elegant manner.

Figure 20 presents an overview of the workspace included in the second prototype of Helaba, indicating the link between artefacts and two core features: *Notes* and *Decision Cards*.

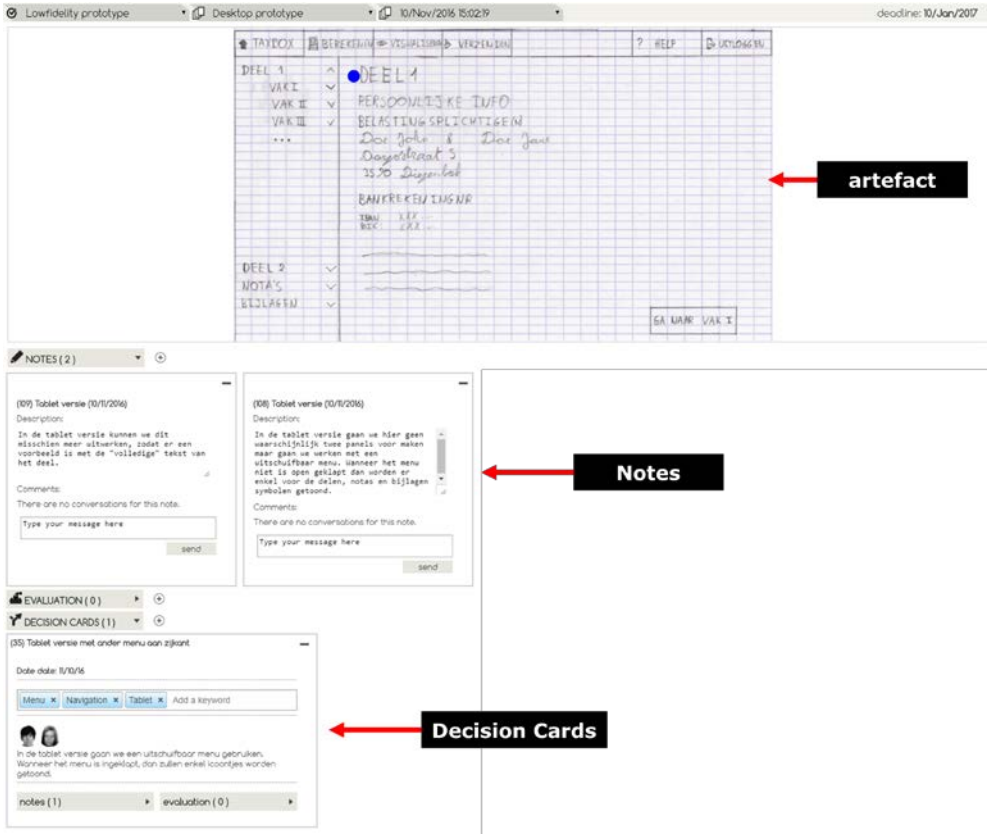

Figure 20. Overview of the workspace of the second version of Helaba.

The section below presents a zoom in to the most relevant features, which are the core of this research, and which evaluation is presented in Part III of this dissertation. In this second prototype, common features to enable interaction (e.g., mechanisms for creating a project, uploading an image, and adding team members) were also elaborated.

4.6.1 Notes

Helaba supports artefact-based communications with *Notes*. The Notes are annotations that can be attached to an artefact, in analogy with traditional post-

it notes. The goal of this feature is to support designers to externalize ideas and comments that can be related to a specific part of an artefact. This link between artefacts and annotations can promote engagement with artefacts (Matta et al., 2001), and serve to document design rationale (Potts & Bruns, 1988). Individual Notes can also be used to start a conversation thread, where team members can discuss about the artefact at hand. Figure 21 presents an artefact (top), and its attached Notes and conversation threads (below).

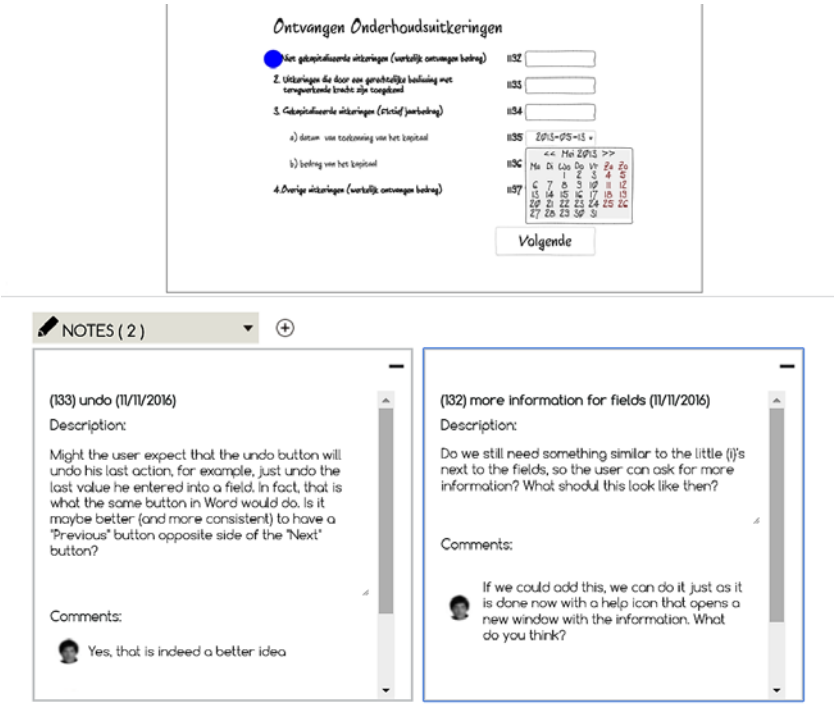

Figure 21. Artefact annotated with Notes (top) and conversations (below).

When a specific Note is clicked, it is highlighted with a blue frame (right corner in Figure 21), and a blue dot (top of in Figure 21) appears to specify the element of the artefact that Note refers to. This feature is used to keep each Note contextualized to which element of the artefact it refers to.

4.6.2 Lean Artefact Repository

Another feature to help design teams to be aware of artefact evolution is the *Lean Repository*, illustrated in Figure 22. A repository for documenting the design work

provides access to insights into ongoing processes (Swan, Tanase, & Taylor, 2010).

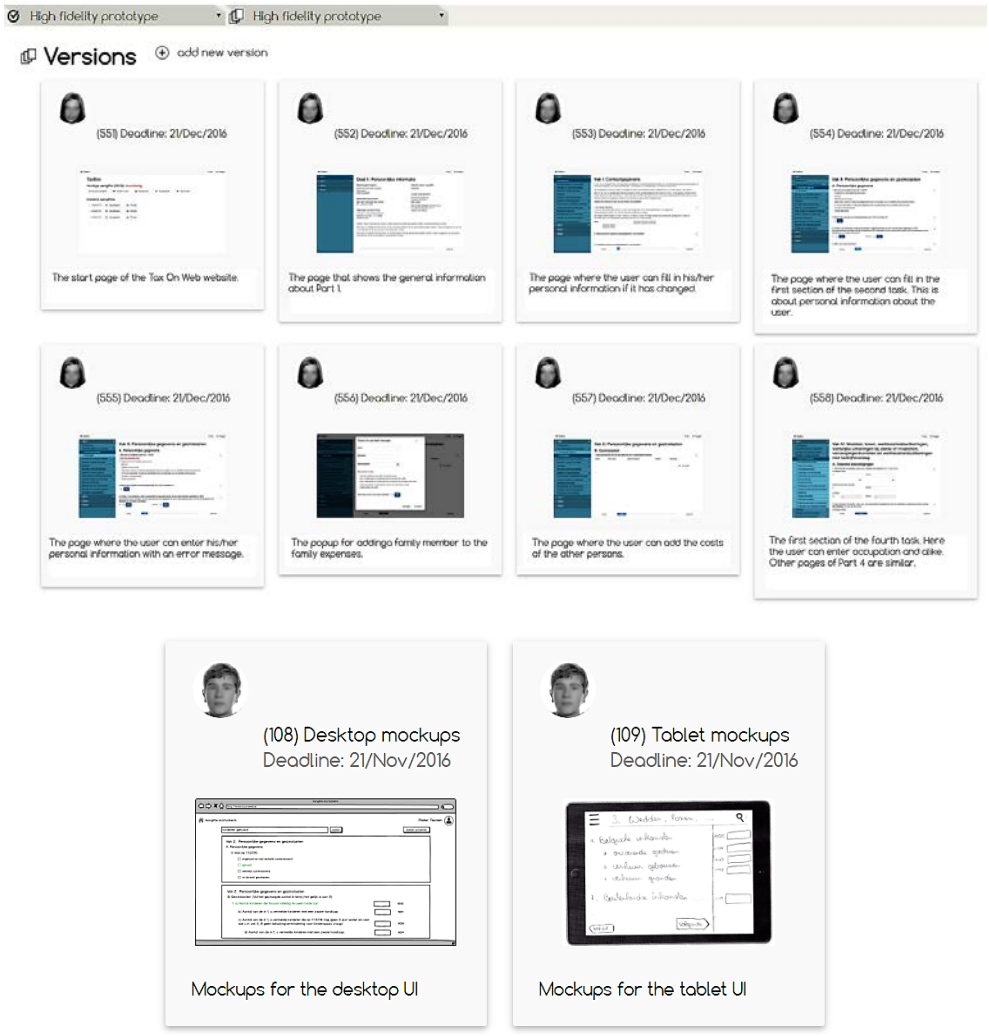

Figure 22. Overview of the Lean artefact repository (top) and zoom-in to the preview cards (below).

Helaba provides a space for storing and organizing artefacts in a hierarchical structure. With this structure, we aim to offer design teams tools to organize files in a more intuitive way. The principle we use in the Lean Repository is that design work can be divided in four levels: projects, tasks, artefacts, and versions. Each project contains one or more tasks, each task contains one or more artefacts, and

each artefact contains one or more versions or elements of the same artefact. For instance, the overview on top of Figure 22 illustrates a task of a project, together with different screens as versions. This particular hierarchy is based on the comment given by various designers over different engagements, where they mentioned to create separate folders for each project (e.g., in Dropbox or local servers). With this idea in mind, we elaborated a simple file hierarchy to investigate if such structure could help to organize large amounts of information. Furthermore, we also experimented by having preview cards (see Figure 22 below), which are small visualizations for navigating between a large amount of artefacts. These preview cards provide a thumbnail of the artefact and a short description.

4.6.3 Decision Cards

Decision Cards, depicted in Figure 23, are meant to externalize individual or collective ideas and otherwise tacit knowledge about decisions. This includes information on why a decision was taken and who was involved in taking the decision. As will be described in Chapter 5, the Decision Cards were explored first as a standalone tool. The assessment of a first version of the Decision Cards with novice designers (see Section 5.4.1) showed their potential value to record design decisions in a flexible way. Thus, we iterated them based on the feedback of designers, and integrated a digital version of the Decision Cards into Helaba (as shown in Figure 23). Within Helaba, the Decision Cards are positioned in parallel to the Notes feature: they are spaces where users can add textual annotations contextualized to artefacts. Decision Cards are different to the Notes feature since the cards provide a pre-defined format for prompting users to record information on what a decision was about, and who was involved in taking it.

Each given visual artefact uploaded in Helaba can have any number of Decision Cards. The granularity of the decisions is determined by the designer, and can range from conceptual or preliminary ideas to concrete technical requirements. The Decision Cards provide suggested fields to capture information about a decision (i.e., title, description, team members, and supporting material). However, the cards do not constrain how or what to externalize as a decision. For early stages in the process, this is essential as many ideas and concepts are still

not well developed. The Decision Cards and their design and assessment are fully elaborated in Chapter 5.

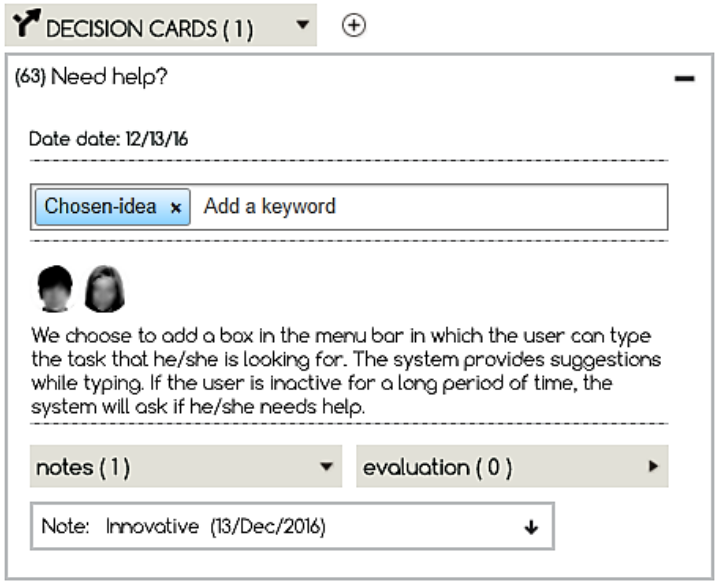

Figure 23. Decision Cards include information about why a decision was taken and who was involved in taking the decision.

4.7 Conclusion

Despite the many different remote communication technologies that are available today, existing solutions fail to support comprehensive communication on design activities and artefacts. In our initial user studies (Part I of this dissertation), designers reported that most of their collaborative problems are due to problematic communication instead of technical limitations. Accordingly, we introduced a tool named *Helaba* to fill this gap by providing a shared workspace for teams to integrate communication with the rationale and evolution of design artefacts over time. We were guided by an UCD approach to develop this tool iteratively. The underpinning of the two prototypes of Helaba are the user studies and design directions reported in Chapters 2 and 3, and the design guidelines introduced in Section 4.3.2. This underpinning expanded iteratively, as knowledge emerged from the different engagements we organized with designers over time (see Figure 1).

As a starting point to create Helaba, we created a *first prototype*, which used an underlying QOC notation as an approach to structure the information. An evaluation of this prototype reveled the shortcomings of using this approach, as structuring the communication resulted more as a burden than a support when it comes to creative design processes. The lessons learnt from this evaluation pointed to opportunities to improve our prototype: *simplify interactions*, *organize and overview artefacts*, and *open a dedicated space for design decisions*. Subsequently, we created a *second prototype* of Helaba, grounded on a better understanding of collaborative – and creative – design practices and their challenges. This second prototype integrated the Decision Cards: a tool consisting of a simple format we explored to record design decisions. The next chapter is dedicated to explore the Decision Cards and their assessment, while the Part III of this PhD deals with a longitudinal assessment of the second prototype of Helaba.

5 Decision Cards: A Format to Capture Design Decisions

In the design process, designers make a wide variety of decisions that are essential to transform a design from a conceptual idea into a concrete solution. As described in Part I of this dissertation, design teams invest time and effort in documenting the rationale of their design work, but this task is up until now considered as cumbersome or too constraining. In this chapter, we describe our holistic approach to design, deploy, and assess *Decision Cards*; a low threshold format to capture, externalize, and contextualize design decisions during early stages of the design process. This chapter is based on the research published by Gutierrez Lopez, Rovelo, Haesen, Luyten, & Coninx (2017). In this study, we evaluated the usefulness and value of Decision Cards with both novice and expert designers. Our exploration results in insights into how such Decision Cards can be used, into the type of information that practitioners document as design decisions, and highlights the properties that make a recorded decision useful for supporting awareness on and traceability of the design process.

5.1 Introduction

Designers are knowledge workers with a creative mindset that helps them achieve the goal of a design project. These solutions, which often represent designer's style and craft, emerge from an unconstrained, free flowing stream of ideas and brainstorming among the different partners of the project (Warr & O'Neill, 2005). In this context, externalizing the outcomes of the design process is a complex task, both for co-located and remote teams. Correspondingly, there is an increased interest in finding appropriate concepts and tools to document the evolution of design processes (Dalsgaard & Halskov, 2012; Dalsgaard, Halskov, Bardzell, Bardzell, & Lucero, 2016). Existing tools that serve this purpose, which emerge mostly from the design engineering domain, are not adopted due to the "extra effort" that they require from designers, and due to the fact that they often

interrupt the creative flow (Horner & Atwood, 2006). The reader should refer to Section 4.2 for an overview of these existing tools.

Previous research has identified three problems related to the lack of detailed documentation of design rationale (D'Astous et al., 2004; Haug, 2015; Mentis, Bach, Hoffman, Rosson, & Carroll, 2009): (1) the iterative nature of the design process means that ideas are explored and expanded, but possibly also discarded or radically changed, making it harder to keep track of the rationale behind each idea; (2) a free flow of ideas can be disrupted by documentation activities; and (3) documenting design decisions in collaborative settings is more complex given the various stakeholders that are directly involved in the decision-making process.

Despite these problems, keeping track of how designs evolve toward a final design proposal has high value (Klemmer, Thomsen, Phelps-Goodman, Lee, & Landay, 2002). A clear communication on how a design artefact was realized makes a proposal more acceptable (Stacey & Eckert, 2003). Externalizing the design process reveals useful knowledge on how issues were resolved or on important bottlenecks that appeared during the process. As such, it contributes to document good practices and "bad smells" (that indicate a decision bottleneck could occur) for later use. Documenting design proposals can be useful for increasing awareness, and promoting the team and self-reflection on the design process (Dalsgaard & Halskov, 2012). However, despite the value of capturing design rationale, it is not widely adopted by design practitioners due to a mismatch with their work practices (Burge, 2008; Horner & Atwood, 2006). We address these problems by tackling the challenges to record design rationale with a suitable tradeoff between effort and benefits.

We propose *Decision Cards* as a tool to make design rationale concrete by documenting it in a lightweight format, namely simple cards with text. Decision Cards are open and flexible, as they do not force any specific technique for recording design rationale. We designed and evaluated Decision Cards by taking a pragmatic, bottom-up approach based on the design directions reported in Part I of this dissertation, and the design explorations with Helaba reported in Chapter 4. By documenting design rationale within fast-paced projects in a systematic way, we address a core need of designers working in commercial settings. This

chapter explores how novice and expert designers use Decision Cards to record design decisions. Subsequently, we analyze the value of Decision Cards when presented to team members external to the design process. Our findings demonstrate that the informative and actionable format of Decision Cards provides a good fit for integration in design activities, supporting awareness and traceability without constraining creativity.

5.2 Related work

Design is a reflective practice where a designer actively transforms an artefact, appreciates the consequences of this transformation, and continues reshaping the artefact until it reaches a desired form (Schön, 1983). Reaching this desired form is a gradual process which involves a co-evolution between the problem and solution spaces (Dorst, 2006; Dorst & Cross, 2001). The process of "framing and reframing" these spaces is at the core of creativity (Dorst & Cross, 2001; Schön, 1983; Warr & O'Neill, 2005). It is widely accepted that this co-evolution of design problems and solutions is a social process (Dorst, 2006; Warr & O'Neill, 2005). For a solution to be recognized as such, it needs to be accepted by relevant stakeholders from different disciplines (Buchanan, 1992; Dorst, 2006).

Designers working in the UI design of interactive systems produce tangible artefacts, such as sketches and prototypes, which are communicated to and negotiated with a diversity of stakeholders. The work of a designer in such teams (as in any other design discipline) is to create artefacts that represent a design, which is then materialized by other team members (Schön, 1983). Shared artefacts serve to create an "external memory" for the team (Cross, 2001), maintain common ground, and facilitate the decision-making process (Dow et al., 2011; Mentis et al., 2009). However, design teams seldom keep track of the process that leads the evolution of visual artefacts. Thus, the reasons that explain the current state of an artefact – its rationale – often get lost (Shum & Hammond, 1994). The process followed by the team to adopt a solution in order to realize the design, depicted by the artefact, remains implicit in the memory of designers or, in the best scenario, hidden in formal documentation or team conversations (e.g., e-mail or chat threads) (D'Astous et al., 2004; Shipman & McCall, 1997).

The lack of a proper record of the design rationale can lead to several problems. For example, it can lead to misunderstandings regarding the next steps in the project (the evolution of the design), or underestimations of the effort that preceded a certain design proposition. These problems could ultimately lead to limited understanding or acceptance of a proposed design solution (Stempfle & Badke-Schaub, 2002). Keeping track of the rationale could potentially solve these issues, although such activities force designers to invest time and effort (Shum & Hammond, 1994).

5.2.1 Approaches to Design Rationale Documentation

Many approaches have been explored to capture, retrieve, and use design rationale in an effective way, but it remains an open challenge to create such a record with an adequate tradeoff between efforts and benefits. We use the three core perspectives proposed by Shipman and McCall (1997) to explore the advantages and limitations of the different approaches to design rationale (argumentation, communication, and documentation). In Chapter 4 we discussed the argumentation approach. The advantages of this perspective and limitations are summarized in Table 6.

Documentation perspective	
Goal	Capture rationale with a structure, but without influencing the design decisions
Approach	Structured record of design decisions, together with information about who made those decisions and when
Advantages	Communicating to externals what has been done; widely adopted by designers
Limitations	Capturing information can be time consuming; relevant information might be lost

Table 6. Goals, approaches, advantages, and limitations of the documentation perspective to capture design rationale (Shipman & McCall, 1997).

While the argumentative tools and notations offer a valuable insight into how to facilitate the decision-making process and to exchange information to reach consensus, their adoption among professional designers is limited (Burge, 2008; Horner & Atwood, 2006). A reason for this is the fact that the argumentation perspective imposes a structure in the design thinking, which results cumbersome for designers. In this chapter, we explore the documentation perspective.

Decision-making in design teams usually happens in face-to-face settings, both in formal and informal contexts as designers communicate, negotiate, and reach consensus on design decisions with stakeholders (D'Astous et al., 2004; Haug, 2015; Stempfle & Badke-Schaub, 2002). Despite the existing systems for capturing design rationale, designers are more interested in doing design work than in recording it, especially since the benefits of this documentation are not evident and immediate (Dalsgaard & Halskov, 2012). Our work has been informed by using a bottom-up approach, meaning we started from input, feedback, and the wishes of active practitioners on documenting design rationale. More specifically, we tackle the challenges of keeping track of artefact evolution and justifying design decisions over time, as reported in Chapters 2 and 3. Instead of focusing on creating solutions for specific decision-making processes, we explore approaches for supporting designers to record the rationale of their design decisions without significantly constraining their way of working. In the next section, we explore approaches and tools for documenting design rationale using design artefacts.

5.2.2 Documenting Design Rationale through Design Artefacts

A variety of tools and approaches have been proposed to document the rationale of the design process, aiming to diminish the time and effort needed, and matching its capture to the "wicked" nature of design tasks (Buchanan, 1992). In the HCI field, some approaches investigate how design rationale can be attached to tangible artefacts to inspire and guide designers while keeping track of the rationale of their inspiration sources. In addition, there is a growing interest in research through design approaches. RTD aims to document the knowledge gathered during design processes in a way that makes it suitable for communicating with a broader, academic audience (Bardzell et al., 2016;

Zimmerman et al., 2010). Rather than an exhaustive list of tools and approaches, we describe the notable insights learnt from documenting design rationale in a structured way.

One approach is to use tangible artefacts to inspire the design process with the use of design rationale. Wahid et al. (2010) explored how to present visual artefacts together with a textual description of the design rationale with *claims* – a representation that contains the design rationale in the form of positive and negative tradeoffs (Sutcliffe & Carroll, 1999). Similarly, *Inspiration Cards* (Halskov & Dalsgård, 2006) are tangible artefacts used to communicate sources of inspiration within heterogeneous design teams. Using these simple, "low-tech" cards and a roughly structured method during workshops facilitated engagement of team members. Results of these approaches using tangible artefacts suggest that using standardized templates for coupling artefacts with their rationale in a straightforward manner is useful to assist idea generation, decision-making, and communication between designers and externals (Halskov & Dalsgård, 2006; Wahid et al., 2010). However, in both approaches, artefacts and rationale are crafted in anticipation of ideation activities, which might be a limitation for routine design.

Another approach is to document rationale during ongoing design activities. Dalsgaard, Halskov, and Nielsen (2008) propose to use maps to structure and visualize the interrelation between elements of inspiration material and ideas emerged during the design process. Similarly, the *Project Reflection Tool* (PRT) was used to document design projects with the objective of promoting reflection and discussion (Dalsgaard & Halskov, 2012). The experiences with the PRT showed that documenting design should be straightforward and result in immediate benefits for the ongoing design tasks.

In *Design workbooks*, W. Gaver (2011) proposes capturing "design proposals" and associated artefacts as a method for creating design spaces. The workbooks include ideas, approaches, and inspiration for a given design problem. Additionally, they allow ideas to change and progress, as it documents proposals and not final designs. Thus, the value of the workbooks lie in the fact that externalizing early ideas can help designers to concretize and expand them. The

advantages of this approach are that it includes input created by the designers during the design process and represents progress in a visible way. The limitation is that workbooks usually evolve over a long period of time, which makes them less suitable for teams working on fast-paced design projects.

We build upon existing research by adopting the concept of using design artefacts associated with their rationale as a solution to facilitate communication between multidisciplinary design teams. In our research, we analyze how such artefacts could be used to document design rationale in ongoing design tasks, embracing the "ill-defined" and even chaotic nature of design, and attempting to support the decision-making process in a natural, organic way. To this end, we use Decision Cards, a lightweight format for coupling design rationale and artefacts without interfering in the reasoning process. We extend previous research by investigating this approach with design practitioners, seeking to address existing limitations by answering the questions on "what to document" and "what level of detail to use" (Dalsgaard & Halskov, 2012).

5.3 Decision Cards

Decision Cards document design decisions related to a set of artefacts that evolve toward the final design. A Decision Card captures three properties of a design decision: (1) *what decision was taken*, (2) *why it was taken*, and (3) *who was involved* in taking the decision. Decision Cards emerged in response to the need detected with design practitioners to be able to keep track of a project in the long term. As reported in Part I and Section 4.5 of this dissertation, designers working in commercial settings consistently report problems such as keeping track of "who said what?" and "why was this option chosen?" Current solutions reported by designers include creating meeting minutes and tracking e-mails. However, retrieving design rationale is considered to be too cumbersome or time consuming. Particularly, we were inspired by how designers created a variety of records, such as videos and minutes, pointing to agreements reached during meetings, and used them as reference points to move the process forward (see example in Section 3.6.2, and design direction in Section 3.7.3).

Decision Cards try to support these practices and tackle these issues with a minimally structured approach to document design activities. We focus on

supporting the early stages of design, where communication around visual artefacts, such as sketches, pictures, and notes, has an important role in the generation and selection of ideas (Cross, 2001; Sharmin & Bailey, 2011). In addition, we aim to capture design rationale without influencing or interfering with the design thinking or its outcomes. These cards are to be positioned “on top” of design activities, and as such, they do not directly structure discussions or their outcomes.

We explore ways to put minimal structuring into practice, and investigate the perceived value of Decision Cards. We defined a basic Decision Card with a format to document specific information about a decision, but without guiding the decision-making process. Shipman and McCall (1997) found that documented decisions need to include “what decisions are made, when they are made, who made them, and why” to facilitate externals to understand the recorded rationale. Consequently, our Decision Card template includes a set of basic information fields (see Figure 24): (1) the *title* of the decision, (2) a *description* of the decision in natural language (free text space, no structure is imposed), (3) the *list of team members* involved in making the decision, and (4) *supporting material* that is related with the design decision, such as sketches, pictures, and notes.

We followed an iterative process to design and assess Decision Cards, which resulted in two different formats of Decision Cards. Figure 24 (top) illustrates the tangible format of Decision Cards we used in our initial exploration with novice designers, which is described in Section 5.4.1. The feedback given by these designers was used to iterate the design of the Decision Cards, particularly on how to make the format more accessible. For instance, we changed the label of the field “people involved” to “list of team members” in consideration of the experiences of participants (see Section 5.5.2 for further details). The opinion of these novice designers was key to conceptualize how to fit the Decision Cards into the second prototype of Helaba. Their suggestions pointed out to support the creation of multiple Decision Cards per artefact, and to keep them linked and contextualized with their corresponding artefact. Figure 24 (below) shows the iterated, digital version of the format, which we integrated into the workspace of Helaba, and was used in a subsequent exploration with expert designers.

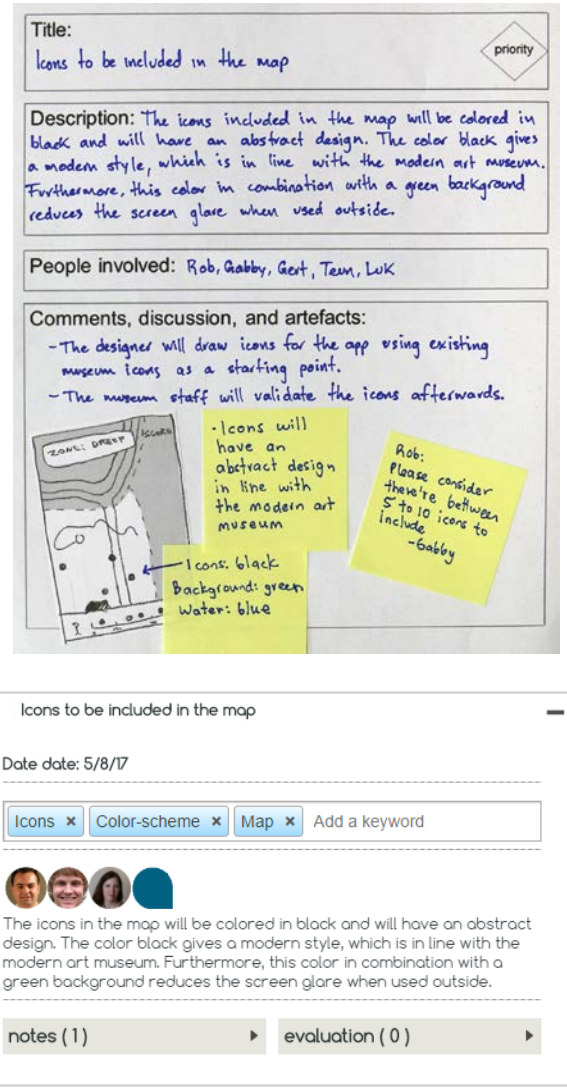

Figure 24.The basic information fields in the paper (top) and digital (below) formats of Decision Cards include: title, description, team members involved, and material related to the decision.

With these predefined templates for the Decision Cards, we attempt to achieve a balance between simplicity and completeness of decisions. These have been identified as valuable characteristics of documenting the design process (Dalsgaard & Halskov, 2012; Shipman & McCall, 1997). In the remainder of this chapter, we analyze how Decision Cards are created by designers and interpreted

by people who were not involved in the decision-making process. Additionally, we explore what aspects of Decision Cards support awareness of, reflection on, and trust in the design process. With this approach, we expect to respect the creative flow of design processes, but to facilitate conveying to externals how and why a design proposal came about.

5.4 Assessing Decision Cards with Designers and Practitioners

We explore the use of Decision Cards by designers and practitioners who are external to the design process. We organized two workshops with novice and expert designers to explore how they use our concept and implementation of Decision Cards to capture design rationale in both co-located and remote settings. We focused on studying the early stages of the design process, when designers are concerned with refining their design goals, exploring, and comparing various design solutions (Cross, 2001). In addition, we conducted a follow-up lab study to analyze how Decision Cards are useful to externalize design rationale to team members not directly involved in the design process. The sections below report on the methodology of the two workshops with designers and the follow-up lab study with practitioners.

5.4.1 Workshops with Designers: Methodology and Participants

We aim to study how designers use Decision Cards to record design decisions rationale. Thus, we organized two workshops: one with novice designers in a co-located setting, and another one with expert designers in a remote setting. This division in two different settings ensured covering a variety of perspectives in the design process. The co-located workshop reproduced the setting in which a group of designers work at the same place/time to solve a design problem. The remote workshop replicated a situation in which designers work individually on a design problem, and share their ideas with people who are in a remote location, such as other designers, clients, and project managers. Remote design work is an increasingly frequent situation, thus, it was important to explore how Decision Cards can support it.

Assessing Decision Cards in controlled – but realistic – settings is a first and essential step to explore the potential benefits/constraints of Decision Cards, and to determine how they could be used for solving real-life design challenges. Including design practitioners in our experimental settings allow us to evaluate Decision Cards with knowledgeable users, but avoiding the unpredictable circumstances that usually occur in real-life design work (Stempfle & Badke-Schaub, 2002).

Workshop with Novice Designers in a Co-Located Setting

We conducted a 3-hour long workshop with six novice designers (three female, three male). All participants (DP1 – DP6) studied industrial design at university level (three Master and three Bachelor students). Participants of the workshop were enrolled in an academic course where they were instructed to prototype a digital application while following a user-centered approach. Hence, participants had previous experience engaging in interaction design and UCD techniques. As a small compensation for their time and active participation, volunteers received a £ 15.00 Amazon voucher. At the beginning of the session, we explained the objectives of the workshop, addressing privacy concerns with an informed consent form. The Decision Cards were briefly introduced as "a template for recording decisions", but it was not explicitly mentioned what information was expected to be included in each individual field. This was done in order to assess the accessibility of the format and technique. A team of two facilitators and one observer conducted the workshop. The facilitators had a neutral role, intervening only to introduce and control the time of the design activities.

Decision Cards were used similarly as *probes* in this workshop. Probes, which can include booklets, cameras, and digital tools, are used in the early stages of design to "sound out the field of design, trying to find and delineate alternative solutions" (Mattelmäki, 2006). The characteristics of probes include: promoting user participation, involving self-documentation, and exploring personal contexts and perceptions (Lucero et al., 2007). Accordingly, we organized the initial exploration of Decision Cards around the idea of using them as probes for documenting a (short) creative assignment. With this approach, we expected to provoke discussion among designers, to allow them to use the cards to document their

decisions “from their perspective,” and ultimately to get inspired by the processes of participants and unexpected usages (Lucero et al., 2007; Mattelmäki, 2006; Sanders & Stappers, 2014).

During the workshop, the students worked collaboratively on a design assignment. The goal of this assignment was to sketch an early prototype for enhancing teamwork awareness. The assignment was guided with two design briefs (see Appendix A.3). Participants were prompted to use the outcomes of the aforementioned academic course as their source of inspiration. The workshop was planned in three steps. The first step was first brainstorming round to generate initial ideas. Participants were grouped in two small teams (T1 – T2) and given a design brief to ideate over a prototype to enhance teamwork awareness. The first design brief was crafted to generate as much discussion as possible, for instance, by thinking on unexpected types of users and situations (e.g., a user who has never been familiar with technology). Participants were asked to record their decisions for this round using a paper version of the Decision Cards.

Next, after a short break, a second brainstorming round took place. Participants were introduced to the second design brief and asked to work as a full group (T3). This brief asked designers to inform each other about the decisions taken in the first brainstorming round, and converge in one solution integrating the ideas of both teams. Again, they were prompted to use the tangible Decision Cards. As a third step, we instructed participants to present the final prototype to the facilitators and observers of the session, who acted as “clients”, asking questions where participants had to justify their design decisions. To conclude the session, we conducted a group interview to find out the experiences of participants during the workshop, and to gather their feedback on how to fit the Decision Cards into a tool like Helaba. Due to scheduling constrains of two participants, one designer left the session after the first brainstorming round, while a new designer joined for the second round. This fact was not considered as a limitation in the methodology, as we expected to capture an open and dynamic design process.

Workshop with Expert Designers in a Remote Setting

For assessing the usage of Decision Cards in a remote collaborative setting, we organized a workshop with five professional designers (two female, three male).

Participants (DP7 – DP11) had an average of five years of experience working in one or more design disciplines, including product and interaction design. All participants had work experience in commercial settings. One participant worked as a freelancer, while four participants worked in a large software company (three as designers, one as design manager). The five volunteers received a £ 10.00 Amazon voucher as a compensation of their participation. The individual tests lasted around 90 minutes and were conducted by a team consisting of a facilitator and two observers. The facilitator had an active role by introducing participants to each scenario and encouraging them to think aloud while performing the tasks, but did not interfere with design activities. The observers recorded the session, making notes and photos.

The design assignment required designers to iterate an early prototype of the dashboard of an app to reduce water consumption. We conducted a pilot test with a researcher from our group to fine-tune the test materials and setup. Designers were individually guided through four scenarios, included in Appendix A.4, which contained inspiration to realize this assignment. The scenarios assumed that the designer was a new team member of the project, who had to get familiarized with existing knowledge in order to propose a solution. We used Helaba for presenting designers with relevant content for this design project, including artefacts annotated with Decision Cards (e.g., storyboards and mock-ups). Furthermore, using Helaba we enabled participants to upload artefacts, add annotations, communicate with the team, and create a digital version of Decision Cards. As suggested by Sanders & Stappers (2014), we used a prototype to “put into action” the design opportunities detected with the Decision Cards. Additional details about the second prototype of Helaba, its design and development, and how it fits the Decision Cards are presented in Section 4.6.

At the beginning of each session, the facilitator introduced the participant to the study, explaining its purpose and addressing privacy considerations with an informed consent form. Additionally, they were asked to fill in a short pre-test questionnaire about their demographic information and background experience. For the main section of the study, the facilitator guided participants through the four scenarios, each containing between three and five tasks. The facilitator encouraged participants “think aloud” while performing the tasks, but gave

minimal hints or cues on how to proceed. The facilitator ensured that the test fitted the assigned timeframe by slightly adapting the tasks in some tests.

The scenario-based evaluation guided participants through a variety of tasks using Helaba. The initial scenarios involved getting familiarized with the content pre-loaded in Helaba about the fictional project (e.g., conversations, decisions, and artefacts) in order to create a new version of a mock-up for a mobile application. Subsequently, we simulated remote asynchronous collaboration as the observers of the session assumed the role of team members. Without briefing the participant about this process, the observers used Helaba to give feedback on the sketches of the designers. Finally, we asked the participants to review the feedback of their team and iterate the solution accordingly. After completing all scenarios, the volunteers were interviewed using a semi-structured protocol to gather their perceptions about Helaba in general and the Decision Cards in particular.

Data Collection and Analysis

We captured audio and video recordings of the co-located and remote workshops. Additionally, we collected information by means of an interview that took place after each workshop. The analysis of the recordings from both workshops looked for recurrent activities, topics, and comments of designers. As an strategy to find out how ideas were transferred through the stages of the study, each of the artefacts produced in each session was mapped to its point of creation. The results from these workshops are eight sets of Decision Cards, as detailed in Table 7.

Setting	*Team*	*Amount of Decision Cards*	*Designers involved*
Co-located	T1	3	DP1, DP2
	T2	4	DP3, DP4, DP5
	T3	4	DP1, DP2, DP3, DP4, DP6
Remote	T4	2	DP7
	T5	1	DP8
	T6	2	DP9
	T7	2	DP10
	T8	1	DP11

Table 7. Decision Cards recorded during the workshop with designers.

5.4.2 Follow-up Study with Practitioners: Methodology and Participants

The aim of the follow-up lab study was to analyze how Decision Cards are useful to externalize design rationale to team members not directly involved in the design process. This lab study simulated the real-life setting where people who are external to the design process, must interpret and use design outcomes (e.g., clients, developers, or designers who come in at a later stage). A lack of context to understand and situate design outcomes, can lead to discarding relevant design elements, or worse, formulation of design alternatives that are less desirable or innovative (Eckert & Stacey, 2000). Thus, our aim is to explore how Decision Cards can facilitate the externalization of design outcomes.

The eight sets of Decision Cards recorded during the workshops with designers (see Table 7) were used as input for this study, which involved eight HCI practitioners (five male, three female) aged between 23 and 38 years. The participants (PP1 – PP8) had an average experience of eight years in the UI design of interactive systems, and all had experience working in a multidisciplinary team. Seven participants had a background in computer science, and one participant in graphic design. The participants were not involved in the workshops conducted with designers. The participants, hereafter referred as *practitioners*, were asked to review the sets of Decision Cards as if they were about to join the team.

Each individual review session lasted around 45 minutes and was led by a facilitator. The role of the facilitator was to introduce the session and the tasks, taking a neutral stance to guide participants during their explorations. For each set of Decision Cards, the practitioners first had six minutes to explore the decisions. Each set of Decision Cards was introduced to the practitioners one by one, and in a randomized order. The practitioners were not briefed about the content, context, or structure of the Decision Cards in advance. After a first exploration, the practitioners had to order the set of Decision Cards based on how important they estimated each of the decisions was. Next, based on the decisions they reviewed, they were asked to answer questions regarding which team they perceived as most trustworthy, which team was having the most acceptable solution, and at which stage of the design process they assume the decisions were

taken. To facilitate data analysis, we captured audio and video recordings. In order to find recurrent or relevant responses, the answers of participants were linked to the set of decisions that they referred.

5.5 Creating Decision Cards during Design Activities

The novice designers involved in the co-located workshop reported to integrate the Decision Cards effortlessly into their brainstorming activities, while the expert designers reported the advantage of using these cards to document and communicate their decisions to other team members, and to sustain them over time. . In both engagements, we found that the minimal structure of the Decision Cards was considered very useful for externalizing ideas and recording agreements, partly because it can be done in a quick and easy way. Designers described Decision Cards as useful, low threshold tools to record design rationale in order to facilitate traceability and awareness about the outcomes of the design process. Next, we present the evidence gathered during our two workshops with designers to support these claims.

5.5.1 How Were Decision Cards Used by Designers?

Design processes guide designers iteratively through activities such as framing problems, generating ideas, and evaluating these ideas in order to define an appropriate solution (Warr & O'Neill, 2005). We found that designers used Decision Cards in two ways: (1) to convey ideas during framing activities and (2) to document ideas after evaluating them. The usefulness of the Decision Cards to support design activities lies in the fact that they provide an overview of agreements, do not constrain design thinking, and can be created in an easy and organic way. A novice designer (DP6) expressed this during the post-workshop interview: *"[It's] very easy to write what you think. You know what your thoughts earlier in the process were. It's good to have an overview of thoughts."*

During the two workshops, we observed that designers used Decision Cards to gather prior knowledge for framing a design problem. Detecting relevant information for reuse can potentially make design processes more efficient (Sharmin et al., 2009). In the co-located setting, designers used Decision Cards to externalize knowledge previously generated by them in an earlier stage. For

instance, the designers of T3 used Decision Cards to externalize *"beginning points for a concept"* (DP3) to be further elaborated. Additionally, Decision Cards facilitated for novice designers to externalize their ideas in a meaningful way.

Similarly, in the remote setting, expert designers used Decision Cards and other artefacts as a starting point for their activities. Decision Cards facilitated designers to retrieve and use existing design knowledge. For instance, participants described Decision Cards as a good way to overview decisions that were taken in earlier stages of a project and why they were made. As mentioned by an expert designer (DP8) during the post-workshop interview, this is especially useful in long projects where team members change:

> *"If I'm in the position where I come in, and the project has been going for a year, and I ask "why is this like that" everybody look at me and say, "I don't remember, but it was discussed in a meeting" […]. If you have Decision Cards, you can just go back and look it up. That makes things a lot easier."*

Expert designers found Decision Cards valuable to overview what decisions were taken and by whom. This last point reveals the social nature of design: the role and active participation of team members in the project is crucial when assessing existing Decision Cards. It was hard for the expert designers to assess the relevance of the documented decisions, as they encountered (fictitious) team members that they never met, and from whom they cannot discover their working style. This finding suggests that Decision Cards should be trustworthy in order to represent an appropriate solution. An expert designer (DP7) highlighted this fact when exploring existing Decision Cards during the workshop:

> *"I reckon these Decision Cards are some way of using the artefacts in validation meetings. You come to a conclusion, and then you make them like really tangible by putting it on these Decision Cards. […] I can see that they [the team] might have a good solution, but I don't know, it can be that [the team's] decisions are a shortcut."*

Our analysis of the two workshops pointed out that Decision Cards documented the outcomes of the idea evaluation activities of designers. Decision Cards represent consensus moments, where a team agreed on a possible course of action. Consistent with previous research (W. Gaver, 2011), we found that articulating ideas in a tangible way facilitated concretizing and expanding decisions. Purposely writing down decisions, as pointed out by one novice designer

(DP4) during the post-workshop interview, was beneficial for self-reflection and traceability: *"[Decision Cards are a] clever way of showing your thoughts. […] Could take some effort to write the thoughts, but also forces to think about it, how to write it down. This is good to keep others in track when absent."*

In the co-located setting, novice designers gradually adopted the Decision Cards as a way of recording and discussing possible courses of action. As the workshop progressed, designers were increasingly confident on how and when to document decisions. The strategies of novice designers for recording a decision was in itself a social process. One team member created the Decision Card, asked the rest of the team for input while writing it down, or read it afterwards to make sure that the entire team agreed with the content. In some cases, this process resulted in amendments and iterations to the content of the decision (e.g., strikeouts and additions). The adoption of Decision Cards was also reflected in the fact that their tangible format was actively manipulated and referred to during discussion, as depicted in Figure 25.

Figure 25. Manipulation of Decision Cards during the co-located workshop with novice designers. Decision Cards are framed in red.

While Decision Cards were used to record agreements, they did not steer designs in a strict direction. Both novice and expert designers either iterated the decisions into a more refined solution or discarded them. In contrast to existing strategies for documenting decisions, such as sketchbooks or digital notes, designers agreed that it was convenient to have a common format to share decisions, as illustrated by DP6: *"Notebooks and notes are very personal, and you need that the other person explains what they were thinking about. The [Decision Card] template*

makes it easier to understand and follow." This quote also reflects on the benefits of having a shared space to document decisions, as they could be crafted for a specific audience, instead of for private reference.

Another recurrent comment was the potential usefulness of Decision Cards for communicating with their teams and other stakeholders, especially if a team member is not active throughout the design process. This is illustrated in a quote by DP6: *"[Decision Cards are] like reading someone's mind when it comes to the project."* Designers found also useful to employ them for personal usage, to go back and remember why certain choices were made, or to reflect on the flow of the project. In consequence, designers did not consider Decision Cards for idea generation, but as an overview of explored ideas. More than a limitation, we consider this an advantage, as Decision Cards did not constrain creativity.

5.5.2 What Information Was Recorded in the Decision Cards?

The analysis of the content of the Decision Cards gathered in our studies taught us that Decision Cards are low threshold tools, as their purpose can be easily understood and completed by designers with minimal guidance. The information recorded in the Decision Cards varied according to differences in personal preferences, team styles, and study conditions. Rather than on the type or quality of each decision, we focus on the completeness of the information recorded in each field of the Decision Cards: *title*, *description*, *list of team members*, and *supporting material* (e.g., sketches or post-it note clusters). We found that these fields were important to construct and externalize a decision, but that the setting and format (paper or digital) in which Decision Cards were recorded had an influence on its completeness.

As shown in Table 8, the fields of *title* and *description* were completed in all the eight sets of Decision Cards (19 Decision Cards in total) we collected. All designers used natural language for recording this information, without using any specific structure or notation. *Titles* included single words or full sentences to summarize the decision, while descriptions included explanations of team agreements, with different lengths. For instance, the *description* of some Decision Cards comprised an extensive reflection about a decision and its implications, while others contained only a brief, simple description. The type of decisions ranged from high-

level ideas to functional requirements. Having a free text space for describing decisions helped designers to document ideas at different levels. This is illustrated with an utterance of a novice designer (DP3), who expressed during the workshop that one of their descriptions was *"quite straightforward, but also a decision."*

	Co-located setting											*Remote setting*							
	T1			T2			T3					T4		T5	T6		T7		T8
Title																			
Description																			
Team																			
Artefacts																			

Table 8. Fields recorded in the Decision Cards by each design team (T1-T8) for the co-located and remote settings. The squares marked in grey indicate that content was recorded in the Decision Card in a given field.

The study setting had an influence on what information was recorded in the list of *team members* and *supporting artefacts* fields. For the co-located setting, the *team members* field (i.e., who took a decision) was overall confusing for novice designers. As shown in Table 8, eight Decision Cards contained information in this field. However, only two included the names of the designers involved in taking the decision. The rest of the Decision Cards included broad terms such as *"all"* (T1) or "*the entire design team and others in the room"* (T3) (see Figure 26b).

When asked about what information they considered to complete this field, novice designers mentioned that they recorded who they thought would be impacted by a certain design decision (e.g., end-users or other stakeholders). We believe that the reason of this confusion was the terminology used in the Decision Cards, and that the face-to-face discussion did not immediately show designers the value of documenting who took each decision. The *support artefacts* field of Decision Cards contains a blank space to attach one or more artefacts related to a decision. Our initial expectation was that participants would directly link a Decision Card to one (or several) artefact. Nevertheless, as shown in Table 8, this was only the case for two Decision Cards created during the co-located workshop. Data analysis revealed an evident link between visual artefacts and Decision Cards, but this connection is not straightforward when looking at the cards as a standalone artefact. Nevertheless, all novice designers agreed during the post-workshop interview that Decision Cards should be attached to artefacts to keep them

contextualized. Figure 26a shows one of the cases where a Decision Card was linked to an artefact. Figure 26b depicts a Decision Card created by T3 where no supporting artefacts are visibly attached.

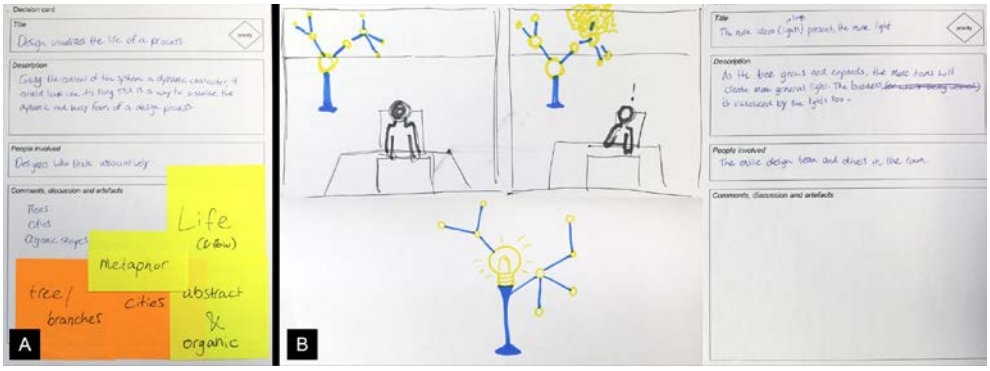

Figure 26. Examples of Decision Cards created by novice designers: (a) created by T2 and (b) created by T3, with supporting artefacts not directly attached to the Decision Card.

For the remote setting, expert designers used Helaba to provide a digital version of Decision Cards and allow other designers to collaborate remotely with them. Figure 24 (below) shows the digital version of Decision Cards. This digital version, which is an iterated version of the initial paper format based on the findings of the co-located workshop.

The digital version includes *comments* and *feedback* fields, list of *team members* involved in the decision, as well as a set of user-defined *keywords* that classify the decision. Expert designers considered the *team members* field intuitive and relevant. However, the remote setting of the study and lack of familiarity with the activities of the other team members led designers to be more cautious on who to mention as a part of their decisions. The digital version encouraged designers to create a strong link between supporting artefacts and decisions, since this link could be identified explicitly in Helaba. Designers added a main visual artefact, such as an early mock-up, together with Notes and Evaluations, which act as virtual equivalents of post-it note clusters and team deliberations within Helaba. Figure 27 presents a Decision Card produced by D8, together with its attached artefacts.

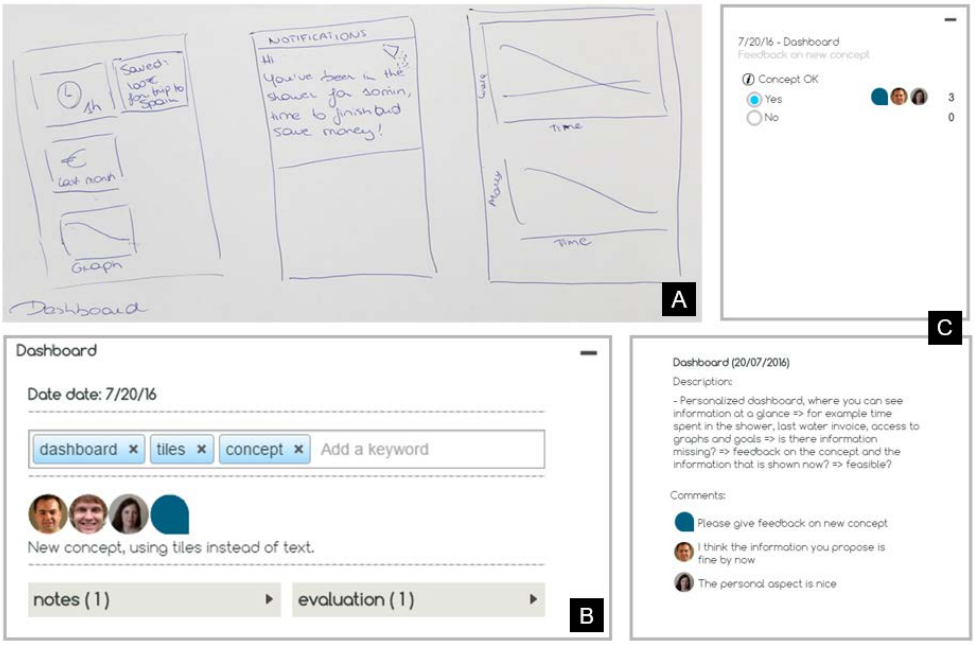

Figure 27. Decision Card created by D8, including (a) early sketch of solution, (b) Decision Card, and (c) evaluation (top) and Notes (below) as supporting material.

The link between Decision Cards, Notes, and Evaluations was well-received by the participants. All linked their Decision Cards with the Notes and evaluations created during the study, even when this was not required by the system or scenarios. During the post-workshop interview, participants suggested to create decisions in a simpler way by using Notes and evaluations to populate some fields of the Decision Card in an automatic way (e.g., title and team involved). For instance, DP7 suggested to add a functionality to "close" an evaluation topic to create a Decision Card automatically with the results of the poll: *"I would kind of create a Note, put an evaluation question attached to it, and bam! Then we have a decision and we move forward with it. Or if there's still disagreement, you can continue the conversation, add another question or something like that."*

Besides the fields reported above, we also experimented with secondary fields, such as *priority* (paper version) and *keywords* (digital version). The *priority* was vastly ignored by novice designers, as they considered it difficult to prioritize design elements. Nevertheless, this was a crucial characteristic for expert

designers, since they need to prioritize the decisions for the project (e.g., requirements to be included in a given version of the artefact). Expert designers also mentioned the usefulness of *keywords*. However, they highlighted the need of a more automated tagging process that could potentially facilitate organizing and retrieving Decision Cards in an efficient way.

5.6 Interpreting Design Decisions by Practitioners

The results of the workshops with designers reported in the previous section showed that Decision Cards are useful, low threshold tools to document and externalize design rationale in an easy way. We believe these characteristics can facilitate awareness about the outcomes of the design process for people not involved in it. To investigate this aspect of the Decision Cards, we organized a lab study involving practitioners external to the design process to interpret and contextualize the Decision Cards created by designers. Results of the lab study indicated that practitioners were able to easily understand the structure of Decision Cards. Furthermore, the Decision Cards seemed to facilitate awareness on the flow of ideas and decisions taken by the design team. In this section, we describe what makes a design decision trustworthy and understandable, thus what constitutes a good documentation of a solution.

5.6.1 What Makes a Decision Card Trustworthy and a Solution Appropriate?

The lab study showed that the completeness of a Decision Card defines its trustworthiness and appropriateness. It is not surprising that practitioners deemed Decision Cards as complete when (1) decisions help to clarify the design process and rationale of the artefact, and (2) decisions include the opinions of different team members. Both imply that a Decision Card needs to contain sufficient information about both the decision itself and the process followed to reach it.

During the lab study, we asked practitioners to select the most trustable and appropriate solution from our workshops with designers. The solution proposed by T1 was selected by five practitioners as the most trustable and appropriate. The characteristic that made this set of decisions stand out from the others was

that decisions were high-level, yet concrete enough, to guide the early stages of the design process. This is illustrated with the quote of a practitioner (PP8): *"[I trust T1 the most] because the ideas are quite concrete and applicable to the context [of the project]. Also I have the feeling that they were talking about ideas that are more important […]. It was talking about concrete ideas to make it work."* However, completeness should not be confused with level of detail. On the contrary, the lack of technical details is an indication of an open, and less limiting creative process during the early stages of the design process. In the context of the design assignments used for the workshops, high-level decisions were perceived by participants as more creative. Decision Cards that contained many technical details were trusted the least by the practitioners.

For participants, including who is involved in the decision and why such decision was reached, made the decision appear as trustworthy, as described by PP2: "*The decision says, people involved: "all." Decisions record the process, so everybody knows this decision and why*." We found that the trustworthiness of a Decision Card is also related to team involvement, and specifically an active and meaningful involvement. Additionally, including indications on timeframes, task division, usability, and end-user acceptance can also increase the value of the decisions.

Considering all responses gathered during the lab study, the most recurrent reasons for not fully trusting a set of decisions were: (1) vague content or missing elements, (2) spelling and grammar mistakes, (3) lacking a clear link between the decision and subsequent versions of the related design artefact, and (4) a mismatch with the stage of the design process that was specified (e.g., already including widget types while still in the early design phase). These reasons often make people feel a Decision Card is rushed, given insufficient thought and discussion, and they are less likely to accept such a decision. For instance, PP6 clarified that the solution proposed by T4 was perceived as the least trustworthy because of the mismatch between the decision and its supporting artefact: *"[The Decision Card] presents misleading information, I don't understand from which circle diagram it is talking about*."

5.6.2 What Makes a Decision Card Understandable?

We found that Decision Cards are understandable when (1) decisions are concrete and concise, and (2) decisions are clearly linked to a related design artefact. The consensus from practitioners was that decisions that include a clear title and a concise description, addressing the rationale, are more understandable and informative. Having a balanced amount of structured text and artefacts was preferred, as described by a practitioner (PP7): "*I think [T2] is more concrete. This one [T3] focuses on really tiny details. And this one [T2] has the structure and yeah, the overall ideas, but also motivation [is] a bit clearly organized*."

Furthermore, information about a version number and date was mentioned as useful to contextualize a decision and facilitate its understandability. The understandability of Decision Cards is enhanced if it includes concrete points of action as this information documents how the decisions fit into the design process. For participants, Decision Cards that clearly state what should be done next by the design team (e.g., requirements, graphic guidelines, or concepts to explore) facilitate its inclusion into design activities.

5.7 Decision Cards as Tools to Document Design Rationale

In the previous sections, we described how Decision Cards were created by designers and interpreted by people who were not involved in the design process. Our findings highlight the fact that Decision Cards are *informative*, as they serve to record agreements for future reference, and *actionable*, as they externalize design outcomes and activities that are to be undertaken by the design team. Next, we discuss the implications, advantages, and limitations of documenting design rationale with Decision Cards.

5.7.1 Record Agreements among Design Teams

The information recorded in Decision Cards reflected the outcomes of the idea evaluation activities among design teams. Decision Cards were created to contain information about what decision was taken, why it was taken, and in some cases,

who was involved in taking the decision. The template with minimal structure helped both groups of designers to keep track of their ideas during discussions.

The main limitation in documenting with Decision Cards is consistent with the limitations in capturing design rationale (Burge, 2008; Horner & Atwood, 2006): it slowed down the free flowing stream of ideas, as it took time to create them. However, nine out of the 11 designers involved in our studies claimed that they were willing to adopt Decision Cards in light of the potential traceability of long-term projects.

During the post-workshop interviews, we prompted designers to reflect on how Decision Cards could fit in their professional practice. Five out of six novice designers mentioned that Decision Cards could serve to focus and synchronize team discussion, and to spark inspiration within the boundaries of the design problem. Additionally, novice designers considered Decision Cards as a "*pile of landmarks*" (DP3) that could be used to reference their deliberations and agreements in a more useful format than traditional collaboration tools (e.g., online repositories and e-mails). The five expert designers valued the use of Decision Cards in one or more of the following situations: (1) large projects involving many team members, (2) projects that run over an extended period of time, (3) multidisciplinary settings where people with different backgrounds need to be informed about the design results, but not about the process, and (4) projects where teams change frequently.

5.7.2 Externalize Agreements to Heterogeneous Team Members

In large, heterogeneous teams, keeping a record of design rationale can serve to increase the acceptance of a proposed design solution. We found that Decision Cards were useful to externalize ideas within design teams and to people external to the design process in a quick way. However, not all Decision Cards were constructed nor perceived by externals in the same way. These results are consistent with previous research that elaborates on the challenges of what content and what level of detail to document as a decision (Shipman & McCall, 1997). We synthesized three properties that helped to valorize a Decision Card in terms of awareness and influence on the perceptions about the proposed design solution.

Complete

Decisions that include concrete information and details about why a decision was taken were perceived as more trustable and led to higher acceptance of the solution. This is related to the fact that the effort invested in creating a Decision Card is associated with the quality of the process and rationale behind it. This suggests that Decision Cards should be iterated to solve the tension between creating Decision Cards without disturbing the creative flow and including the correct amount of information. We found that using a digital version of Decision Cards facilitated for designers to include more information. However, it is clear that more content does not always generate more trust in the decision. For instance, if a Decision Card associated with the early stages of the design process contains many (technical) details, it is perceived as a less valuable decision since it does not document the ideation process that led to a solution.

Connected

Decisions that are linked to artefacts, previous decisions, or support material (e.g., artefacts or Notes) are perceived as more valuable. Connected decisions provide an overview of the evolution of an artefact making the flow of ideas evident. With connected decisions, a stronger rationale is built: following the links between decisions, various aspects of the resulting design get an underpinning. It adds traceability that can be used to track the evolution of a project from the beginning up until the most recent design decision.

Inclusive

Decisions that include a larger representation of team members involved in a project were more interesting: they involve multiple opinions and perspectives. Decision Cards that include relevant questions and/or discussion were considered as more inclusive, even if less team members were explicitly mentioned. This type of content as part of a Decision Card implied that the voices of the team members had an impact on the design process. Note that the roles that are represented by team members listed on a Decision Card, are also considered to be an important aspect. If an essential role is missing (e.g., a designer is not part of a decision on graphic layout), the Decision Card might lose its value.

These properties are guidelines to inform design rationale systems on what content and level of detail to record as a decision. We argue that a minimally structured way of documenting decisions provides a suitable tradeoff between efforts and benefits for capturing and retrieving design rationale.

5.8 Conclusion

While there are existing tools and notations to record the design decision rationale, they remain unused as they fail to incorporate the practices of design teams. In this chapter, we proposed an approach to capture and externalize design decisions in an active, organic, and straightforward way: *Decision Cards*.

As a first step, we organized a workshop where novice designers used the first version of the Decision Cards as a probe to explore design opportunities. The feedback and insights gathered from this experience served to create a second version of the Decision Cards, which was fitted into the second prototype of Helaba. This prototype was used to facilitate a workshop with expert designers, were we explored how Decision Cards could be used in the context of teams working remotely.

The results of our studies showed that Decision Cards allowed designers to elaborate on their decisions freely. Furthermore, Decision Cards facilitated team members to understand the flow of ideas and decisions taken by a team, even when these team members did not take part in the design process. Decision Cards provide a way to reflect on the design process both to each team member individually and to the design team. We consider Decision Cards as a starting point to create a bridge between structured and rigid documentation of design rationale, and an approach that matches the free flow of ideas that characterizes the design process. Decision Cards can be used “on top” of a variety of design activities (e.g., workshops, design meetings, and brainstorm sessions), acting as a format to record decisions reached, without guiding their decision-making process. Given the *actionable* and *informative* format of Decision Cards, they can be used from the conceptual stages to the later stages of the process.

A potential shortcoming of the Decision Cards is that they require designers to spend some time and effort in documenting the decision. However, designers who

created Decision Cards in our studies creating recognize the long-term benefits of having such a record of their process. The evidence we gathered in controlled but realistic situations suggests that Decision Cards, in combination with design artefacts, can be used for supporting awareness and traceability on the design process.

Our explorations with designers included a variety of settings and levels of expertise in order to have a broad overview on potential usages for the Decision Cards. This variety gave us insights in how these cards could be valuable to record decisions in a lightweight way in different contexts. However, it is a potential limitation that the level of expertise (e.g., novice or expert designers) or study design (e.g., setting and design assignments), could have shaped the engagement of participants with the Decision Cards. Consequently, we report our findings while specifying if the insight came from a novice or expert designer, and the setting of the study (i.e., remote or co-located). Moreover, we avoid making inferences on the skills of the designers or the quality of their design outputs. Instead, we contrast objective data contained in the cards, such as fields recorded (see Section 5.5.2). With this analysis, we gathered information on the format of the Decision Cards, and how they can be fitted in a design process. Recognizing the value of exploring *what content is recorded in Decision Cards*, we organized a longitudinal study to investigate this aspect, as will be reported in Part III of this dissertation.

Part III: Evaluating the Approach to Documenting Design Rationale and Decisions

6 Recording and Revisiting the Evolution of Design Artefacts

Keeping track of design processes is a cumbersome task due to the apparently unconstrained and unstructured nature of creative work. Traceability is relevant to revisit and reflect on the design narratives that describe artefact evolution. In this chapter, we seek to bridge the gap between formal and flexible approaches to design documentation by applying the concept of traceability, commonly used in design engineering, into creative design processes. This study and associated findings were previously published in a paper by Gutierrez Lopez, Rovelo, Haesen, Luyten, & Coninx (2018). We aim to identify what characteristics are necessary in an interactive system to facilitate the documentation and traceability of creative design processes. To this end, we use the functional prototype of Helaba, introduced in Chapter 4, to connect artefacts, design rationale, and decisions in a shared workspace. We evaluated this prototype for 15 weeks with six pairs of students engaged in a user-centered design project. Our findings showed that having a repository of artefacts annotated with design rationale can facilitate tracking progress in different phases of the process. Participants found that creating a record of design work is useful to reflect *on* and *for* team agreement, to ensure consistency of evolving artefacts, and to help in planning future steps of the design project.

6.1 Introduction

Artefacts are used by design teams to ground communication, boost creativity, and justify design decisions (Schön, 1983; Wolf et al., 2006). Nevertheless, artefacts provide only a partial representation of design work. The turning points taken by design teams to evolve artefacts in an iterative way is what contains the most valuable information about the design process (Dorst & Cross, 2001). Keeping track of artefact evolution helps to create a “project memory” (Matta et al., 2001), which contains the experiences and knowledge gained during the process.

Many design practitioners are reluctant to adopt tools that track the evolution of artefacts, since they tend to formalize design activities in a specific way. Constraining the design activities can potentially have a negative impact on design thinking (Horner & Atwood, 2006), which is essential for finding creative, innovative solutions. Nevertheless, keeping track of the evolution of artefacts is useful in many ways. First, it can create a shared representation and understanding of the experiences acquired during a project (Matta et al., 2001). Furthermore, previous research suggests that a representation of artefact evolution can support the design process in three ways (Pavković, Štorga, Bojčetić, & Marjanović, 2013; Potts & Bruns, 1988): (1) by ensuring consistency of artefacts since results from one phase of the process are connected to the next phase; (2) by promoting reusability of previously generated knowledge; and (3) by providing resources for design teams to reflect on their approach and progress.

Existing tools that capture the evolution of design artefacts emerge largely from the engineering domain. These tools focus on supporting *traceability* of the design process, a term that is rarely used for creative design practices. Traceability enables design teams to pinpoint where a certain element was introduced into the process, and explore the reasons for its ultimate adoption or rejection (Matta et al., 2001). Thus, traceability can help teams to reflect on the co-evolution of design problems and solutions. In this chapter, we identify the characteristics of a system to facilitate traceability of creative design activities. We frame this concept in user-centered design processes, and adapt it according to the needs and working style of design teams.

Teams working in UCD adopt multidisciplinary perspectives, where communication is based on a variety of artefacts (ISO, 2010). However, the strengths of this process also introduce associated drawbacks. These limitations include keeping track of the evolution of design artefacts and their rationale, and for members of the multidisciplinary teams, getting the same understanding about these artefacts (Göransson, Gulliksen, & Boivie, 2003). When it comes to traceability of UCD processes, there is a tension to retain a degree of formalism and at the same time offer enough flexibility for creativity. In our research, we investigate how design teams document and retrieve information about artefact evolution during a user-centered design process.

Our goal is twofold: (1) *understand how teams document and retrieve their ongoing work*, and (2) *identify what characteristics are necessary in a tool in order to facilitate traceability in creative design*. Achieving these goals requires understanding how teams generate, communicate, and retrieve their ideas over the duration of a project. Thus, we framed a study around a design task that follows the lifecycle of user-centered design, from initial idea generation to high-fidelity prototyping. Our study consisted of a 15-week longitudinal study involving six pairs of students whose assignment was to redesign an interactive application for tax calculations. This project required the involvement of external stakeholders in several stages. To investigate how teams document and retrieve their ongoing work, we asked them to record their collaborative design process using a functional prototype of Helaba. The reader should refer to Section 4.6 for full details about this tool.

This prototype was iteratively designed, developed, and assessed with designers. More specifically, Helaba was underpinned in the user studies and design directions described in Chapters 2 and 3, as well as an iterative design work described in Chapters 4 and 5. This prototype responded to a need of design teams to keep track of their design processes in a simple and flexible way. From the early prototyping stages, we learnt that a shared visual, workspace for connecting artefacts with a description of their rationale can facilitate the documentation of design processes. Using our functional prototype of the second version of Helaba, we gathered the artefacts, communications, and decisions produced by the participants during the design process. Additionally, we periodically collected the feedback of participants to gather information about their experiences. This procedure allowed us to create an extensive picture of the design process followed by each team, thus allowing us to explore traceability.

Findings of our study revealed that documenting the early stages of UCD processes in Helaba was useful to support progress of the different stages in a flexible way. More specifically, it helped participants to keep track of their process by providing a (1) lean structured repository and (2) a shared workspace to keep annotated artefacts and design decisions in a common workspace. We extend previous research by using traceability as a means to bridge creative and

engineering design perspectives. Furthermore, we contribute with a longitudinal evaluation on how design rationale and traceability can be used in UCD processes.

6.2 Related Work

6.2.1 Conceptualizing User-Centered Design

Design is better considered as a process rather than a set of isolated activities or outcomes. Swan et al. (2010) describe design as *processional* given its "unfolding and contingent" nature. The design problems co-evolve together with solutions (Dorst & Cross, 2001). During this co-evolution, wicked design problems – to which there is no clear solution – are explored and refined (Buchanan, 1992). Artefacts are valuable since they embody this processional nature, being refined in an incremental manner and shaped by what was done before (Swan et al., 2010). However, the most useful information is not found in the artefacts themselves, but in the discussion that led to their creation (Wolf et al., 2006) and the knowledge that they reflect (Sharmin et al., 2009). In this way, artefacts portray a partial picture, that serves the purpose of making ideas visible, and provides a space to communicate and refine those ideas (Wolf et al., 2006). Artefacts and the narratives of their evolution serve to understand the design process. Thus, it is valuable to capture and reflect upon the way artefacts are created and refined (Dalsgaard & Halskov, 2012).

There is an ongoing discussion to the degree in which artefacts and creative design processes can be articulated and made explicit to others (Fallman, 2003; Göransson et al., 2003; Wolf et al., 2006). Fallman (2003) proposes three opposing accounts for positioning design: romantic (artistic process), conservative (much as in scientific or engineering domains), and pragmatic (messy and creative by nature). Each of these accounts provide valuable interpretations of how to conceptualize the design process, and how it can be articulated and made explicit to others.

In HCI, part of this discussion is oriented towards the differences in positioning user-centered design as mostly an engineering or a creative design endeavor (Pierce et al., 2015; Wolf et al., 2006). The former implies that design can be

formal and systematized; while in the latter, it is considered a loosely defined process that does not constrain design thinking.

While there is a tendency to position UCD as part of the conservative account, there is limited evidence that structured design processes capture or support the work practices of designers successfully (Cockton, 2014; Göransson et al., 2003; Pierce et al., 2015). These authors evidence the importance of shifting UCD practice from engineering towards a more creative one. Nevertheless, user-centered design projects often require producing an interactive application that can be deployed and tested with end-users (Ju, Ionescu, Neeley, & Winograd, 2004). This implies that tools to support UCD processes should provide a balance between supporting "good practices" in engineering and accommodating the unconstrained nature of creativity.

6.2.2 Bridging Design Accounts to Support Traceability

The Oxford Dictionary (2017) defines *traceable* as something that is "able to be found or discovered" or "able to be followed on its course or to its origin." Being able to "trace every step along the way of how a problem is transformed into a solution, including intermediate results and findings" is important for both science and engineering (Egyed, 2001).

In engineering design, traceability relates to the history of a design, as it enables identification of where certain information was introduced into the process (Potts & Bruns, 1988). According to Neven et al. (2013), traceability is useful as guidance to *look forward* and frame the process, and to follow the origin of design elements. According to Tang et al. (2007), being able to trace back design rationale is relevant for the design process, as it involves artefacts in constant evolution.

Design rationale documents the ideas and process followed to create an artefact: its justification, steps for its creation, and how it is contextualized in the overall process (Moran & Carroll, 1996). Thus, traceability and design rationale are concepts often associated with capturing and revisiting design knowledge. However, a single final design rationale is not enough for traceability, as there should be a link between the rationale and progression of artefacts over time (Potts & Bruns, 1988). This is especially relevant for the early stages of design,

where a large amount of ideas and artefacts are explored and defined (Sharmin et al., 2009).

6.2.3 Engineering Design and Traceability

The concept of traceability has been widely explored in engineering design. Solutions emerging from this perspective focus on formalizing models and steps for recording the design process (Matta et al., 2001). Some of the explored solutions include:

- Requirements modelling to track the evolution of requirements and their integration into development and maintenance tasks (Ozkaya & Akin, 2007);
- Design rationale to structure design argumentations, using formal models to surface the connections between discourses and artefacts (Lacaze & Palanque, 2007; Potts & Bruns, 1988; Tang et al., 2007; Tang, Liang, Clerc, & van Vliet, 2011); and
- Group decision support to identify knowledge that needs to be integrated and traced, and handle the links to support decisions (Mohan & Ramesh, 2007).

The reported benefits of these solutions are (Pavković et al., 2013; Shah, Jeon, Urban, Bliznakov, & Rogers, 1996): (1) early detection of potential conflicts or discrepancies in the design process, (2) the possibility to communicate and justify design decisions to team members from different disciplines, and (3) to facilitate reuse and analysis of design knowledge. Limitations are related to the fact that these solutions assume that design discourse can be made uniform and standardized (Potts & Bruns, 1988; Tang et al., 2007). However, there is little empirical evidence to support how this approach works in practice (Göransson et al., 2003; Horner & Atwood, 2006).

6.2.4 Creative Design and Traceability

Traceability has not been explicitly explored within creative design. However, previous research reports the potential value/benefits of tools to keep track of design evolution over time (Dalsgaard & Halskov, 2012). Therefore, there are a number of solutions that have been proposed to support reusing, documenting, and inspiring the design process. Some relevant solutions include:

- Open spaces to document ongoing design processes, which act as a source of collective creativity and inspiration, promoting free exchange of ideas and feedback between designers (Meagher, Bielaczyc, & Huang, 2005; Swan et al., 2010);
- Shared workspaces between teams to ground communication and to document design knowledge for facilitating its reuse (Dalsgaard & Halskov, 2012; Ju et al., 2004; Oehlberg, Simm, Jones, Agogino, & Hartmann, 2012);
- Typical design artefacts such as sketches (Lindley, Cao, Helmes, Morris, & Meek, 2013; Piya, -, Chandrasegaran, Elmqvist, & Ramani, 2017) and storyboards (Wahid, Branham, Cairco, McCrickard, & Harrison, 2009) to collect, share, and access previous ideas, supporting reuse and inspiration; and.
- Participatory techniques to engage multiple points of view, in which the artefacts produced can serve to document the process, such as *MAP-it* (Huybrechts et al., 2012) and the *Personal Card Set* (Sleeswijk Visser, Van Der Lugt, & Stappers, 2007).

The value of these solutions is that they integrate the creative, progressive nature of design, and avoid constraining the thinking process of designers. As with these solutions, we aim to explore design work in consideration of the existing practices of designers, and avoid imposing a structure to it. We extend these solutions by exploring how the concept of traceability can be fitted into creative practices, and used to bridge these to engineering design practices. We explicitly avoid proposing a specific technique of working. Instead, we use digital tools as an "extra layer" on top to their current practices with the intention of documenting their work in an organic way.

6.2.5 Off-the-Shelf Tools to Support Traceability

A number of (commercial) off-the-shelf solutions have some kind of useful support for traceability. These tools are adapted to the needs of design teams working in commercial, fast-paced projects, where design outcomes are communicated to a large number of actors. We reviewed 16 of these tools in order to understand what is available for designers in terms of traceability. It is not our intention to create an exhaustive list of available tools, but to explore what commercial

applications for designers support traceability. Afterwards, we evaluated the applications according to the design guidelines of Helaba described in Section 4.3: *support artefact-based communication*, *gather feedback in a shared workspace*, and *enable awareness of artefact evolution*. See Appendix A.5 for a summary of the assessment of these 16 commercial tools.

All these applications highlight the need of supporting remote, multidisciplinary design work. Ten out of sixteen tools include a shared workspace that can be used to trace back the history of artefacts. However, none of these applications explicitly target traceability of design knowledge because they do not make the link between pieces of knowledge evident. Conversely, the focus is on supporting ongoing conversations, gathering feedback, and "reducing revisions and approval times" of design proposals. Thus, it appears that most of them aim to be productivity tools rather than creativity tools. The tools that include a shared repository also support teams to organize their files in different ways, such as grouping files into projects. Nine tools include team or task management features, such as the possibility to create Kanban boards, or to assign tasks to different team members. Eight tools offer the possibility to be linked with third-party tools to support project management and team communication.

While these off-the-shelf solutions offer interesting and seemingly beneficial features, it is unclear how they support ongoing design processes. Furthermore, there is no evidence in literature of their proven efficiency for supporting design work, or how (and if) they can be valuable for traceability.

6.3 Helaba as a Tool for Exploring a UCD Process

We use the functional prototype of Helaba to investigate traceability. Helaba was iteratively designed and used as a communication tool to support design teams. This tool allows design teams to connect artefacts, design rationale, decisions, and feedback in a shared workspace. As it has been described in this PhD, we followed an empirical approach to investigate the needs of practitioners (Part I) and iteratively designed and assessed tools for this end (Part II).

In this study, we evaluate three main features of Helaba: *Notes*, *Decision Cards*, and the *Lean Repository*. The reader should refer to Chapter 4 to have further

details about Helaba and its design process. More precisely, in this evaluation we contextualize the functionalities of Helaba (Section 4.6), together with the design guidelines that were used to inform its creation (Section 4.3). The relation between the guidelines (G1 – G3) and elements of Helaba is shown in Table 9.

	Design guidelines	*Core elements*
G1	Support artefact-based communication	Notes
G2	Gather feedback in a shared workspace	Lean Repository, Notes
G3	Enable awareness of artefact evolution	Decision Cards, Lean Repository

Table 9. Design guidelines and core elements of Helaba.

Online shared workspaces facilitate being aware of the activities of others and contextualizing individual activities (Dourish & Bellotti, 1992). During the early stages of design, artefacts are essential to generate and refine conceptual ideas (Sharmin & Bailey, 2011). Therefore, shared workspaces in design help to capture and revisit ideas, and facilitate team collaboration (Ju et al., 2004).

6.4 Methods

6.4.1 Participants and Assignment

A total of 15 participants joined our study: 12 students and 3 UX experts. Twelve participants (SP1 – SP12) ranging from 21 to 25 years old (10 male, 2 female), were part of a Master level computer science (CS) program with HCI specialization. They were enrolled in a project-based academic course where the objective was to create an interactive application while following a UCD approach. The project was to re-design a website for tax calculation and registration for the Federal Ministry of Finances. A group of six members of this Ministry was involved as external stakeholders (i.e., clients) for this project, including experts from both computer science and finances. Furthermore, potential end-users were involved in the first and last stages of the project. This project was selected as students

had to both design and develop an application, which posed a complex design challenge. Students were proficient in building interactive systems and software engineering, but had no creative design education. Three more participants, UX experts (EP1 – EP3), joined around the mid-point of the academic course. These participants were HCI researchers with an average of 7 years' experience. Their role was to evaluate the usability of low-fidelity prototypes created by the students. We selected this project as a basis for our study as it involves: (1) a real-life design case, (2) external stakeholders (i.e., end-users and clients) and internal stakeholders (i.e., UX experts), (3) collaborative design work, and (4) it follows the life-cycle of the UCD process, from initial exploration to final solution.

6.4.2 Phases and Activities of the Project

For the academic course, students were grouped in six pairs (T1 – T6). They were guided through four phases typically associated with UCD projects. Table 10 presents a high-level overview of the four phases of the process that were required, as well as people involved.

Phase	*Activities*	*1*	*2*	*3*
User analysis	Interview end-users and clients	■	■	
	Analyze and define initial requirements	■	■	
	Create personas and scenarios	■	■	
Task analysis	Explore existing application	■		
	Create task and dialog models	■		
Low-fidelity prototype	Create *early prototypes* to explore alternative solutions	■	■	■
	Usability evaluation of prototypes (involving UX experts)	■	■	■
	Present a preliminary solution to clients	■	■	■
High-fidelity prototype	Workshop to generate new ideas	■	■	
	Create an interactive prototype of the chosen solution	■	■	
	Usability evaluation of the prototype (involving end-users)	■	■	

Table 10. Phases and activities of the project, and involvement of (1) students, (2) end-users/clients, and (3) UX experts.

The phases served to scaffold the design process (e.g., activities to follow and artefacts to be delivered). However, each student pair was free to decide on how to implement the design process in terms of tool usage and content to document.

The *user analysis phase* included a briefing with the client and a round of interviews with representative end-users to underpin an initial understanding of the design problem. The students were instructed to create personas and scenarios with the knowledge gathered. The *task analysis phase* focused on architectural software design, where students created an early, high-level representation of the solution using task and dialog models (i.e., formal engineering notations). The *low-fidelity prototype phase* involved the creation of sketches and prototypes (both paper and digital) to define initial user interfaces. In this phase, the usability aspects of these prototypes were evaluated by UX experts. Furthermore, a face-to-face session with the clients was organized to gather feedback about the selected approach. Finally, the *high-fidelity prototype phase* included the development of an interactive system using source code. The usability of the resulting prototype was evaluated with representative end-users.

6.4.3 Experimental Design

At the beginning of the academic course, students were asked to voluntarily join our study, which all of them did. We explicitly disclosed to students that they were taking part of a research study, and offered them an informed consent form. At the beginning of the study, we introduced Helaba to the students (e.g., functionalities and workflow), and asked them to use it for their collaborative activities “in the best way possible.” There were no specific requirements on how, when, or where to document, so participants had freedom over the use of our system. Notice that Helaba is designed to support UCD processes, but implies no restrictions on the way the UCD process is executed in practice (e.g., phases to follow and artefacts to add). To promote neutrality and encourage participants to record as much content as possible, it was agreed that the content uploaded to the system would not be evaluated in any form unless explicitly stated. As an incentive, students were offered an extra half point on their grade (0.5/10), which thus had very limited impact on their overall performance in the course.

The study had a duration of 15 weeks, which is the length of an academic semester and the aforementioned course. In addition, two weeks of holidays between semesters were included, but no tasks in the context of this UCD course were assigned during this period. Throughout the academic course, we gathered

information on the process followed by each team by monitoring the content they uploaded to the system. In addition, we collected participants' feedback at regular intervals.

6.4.4 Data Gathering and Analysis

After each phase of the UCD process, students either participated in an interview or filled in an online survey. Figure 28 presents the monitoring techniques used throughout our study: interviews, online surveys, and focus groups.

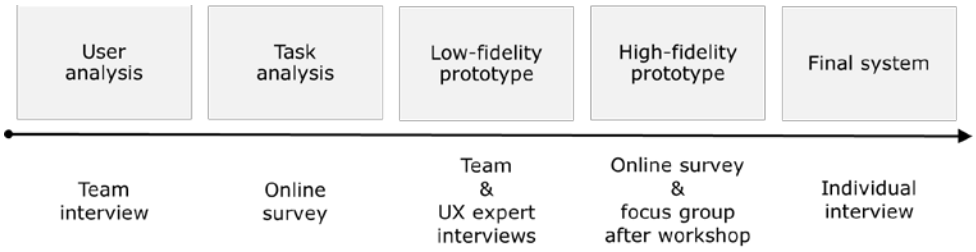

Figure 28. Monitoring techniques used in each UCD phase.

We alternated between monitoring techniques to collect information on different levels. However, we asked similar questions in each phase of the study in order to draw comparisons, such as frequency and purpose of use of Helaba, and other tools used.

The interviews were used in key phases of the project to explore in-depth the practices of the participants. Interviews held during the user analysis and low-fidelity prototyping were conducted in pairs, as we wanted to contextualize their collaborative design work. The final interview was individual to explore the perception of each participant about how Helaba facilitated teamwork and self-reflection. Furthermore, we interviewed the three UX experts who performed usability evaluations during the *low-fidelity prototype phase* about their experiences using Helaba for the evaluations. Additionally, we conducted first a workshop and then a focus group during the *high-fidelity prototype phase*. In the workshop, participants used Helaba to revisit previously explored, but discarded ideas to generate new features for their prototypes. The focus group involved all students, and was used to gather their opinions and experiences during the workshop.

Online surveys were used to collect the same information as in the interviews, but in a more concise way during the *task analysis and high-fidelity prototype phases* (see Figure 28). The survey is available in Appendix A.6. The online surveys were undertaken individually or as a team. We asked teams to fill in one survey per team, but some teams found it easier to fill them in individually. In four instances (11% of responses), we detected a discrepancy between the answers of teams who filled in the survey individually. For instance, one team member reported to "upload all artefacts" while the other member reported to "upload some artefacts." For these instances, we took a conservative approach and reported the least positive answer.

Our experimental design allowed us to monitor key aspects of the design processes followed by participants (e.g., goals of the project, deliverables produced, and timing). Since all teams received the same instructions and worked under the same conditions, this approach enabled us to compare results across teams regardless of the amount, type, and quality of content they recorded. As pointed out by Stempfle & Badke-Schaub (2002), this experimental design would be very difficult – if not impossible – to achieve in an "in-the-wild" design project (e.g., with professional designers in a design consultancy) due to the highly unpredictable nature of design projects. Furthermore, the selected project and population allow us to explore a full cycle of UCD project with novice designers, which we believe can benefit from traceability of their processes.

We gathered data by recording audio and video of the interviews conducted through the study. The workshop and focus group were also audio and video recorded, and two observers took notes. We completed our dataset with the responses given by participants to the surveys. We compiled the data to create a matrix of responses according to the UCD phase in which they were captured. This analysis allowed us to find patterns in the work style of each team, and to understand how they used Helaba throughout the study.

6.5 Documenting a UCD Process with Helaba

The design assignment of the academic course guided participants through the typical phases of a user-centered design process. While all teams had similar tasks, each team used a particular strategy and set of tools to facilitate teamwork.

For instance, when remotely located, one team used either Skype or Facebook chat to communicate, while another team only used Slack for their conversations. All teams reported to use a similar strategy and set of tools in similar ways throughout the process. For instance, the team who used Slack as a remote communication tool used it as such through the entire project. This means that a particular strategy for communication was followed regardless of the differences in the activities of each phase. The participants selected the tools they used according to their needs, instead of adopting new tools according to the phase of the project. This finding is consistent with the results reported in Chapter 2 on how professional designers select and adopt tools in commercial design settings.

Unlike other tools mentioned by the participants, the reported uses of Helaba changed during the study. During the first half of the project, participants reported to use it mostly as a repository of artefacts, adding a limited number of annotations to them (i.e., Notes and Decision Cards). The total number of artefacts and annotations added in Helaba supported these comments from the participants. As illustrated in Figure 29, more content was added in the second half of the project, when the core design tasks and bulk of discussion took place. This evolved for all teams in a similar manner.

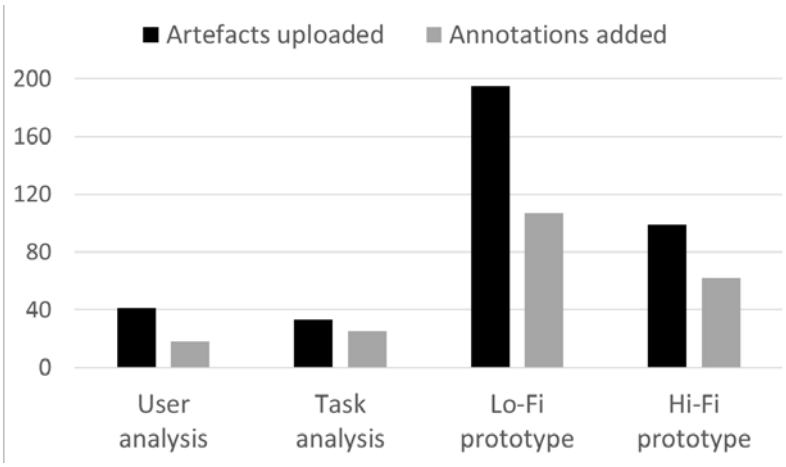

Figure 29. Artefacts uploaded and annotations added to Helaba in the different stages of the UCD process.

Regardless of the work style that each team used, the two core strengths of Helaba for all teams were: (1) keeping a record of previous and future work, and

(2) creating a space to access the work of others. The specific work style of each team was accommodated in Helaba, as it supported teamwork in different ways during different UCD phases according to the particular tasks and priorities. These core strengths emerged as all participants explicitly mentioned them as benefits of Helaba during the final interview of the study, and were consistently mentioned across the different stages of the project. An overview of the mentioned usages of our prototype reported in each UCD phase is detailed in Table 11.

User analysis	Structured repository for artefacts and relevant ideas/decisions
	Keep track of possibilities explored before making a decision
	Not actively used for communication
Task analysis	Structured repository for artefacts and relevant ideas/decisions
	Share progress to team members
	Record milestones and to-do's
	Not actively used for communication
Low-fidelity prototype	Track discussions and changes made (and their rationale)
	Record how things should be iterated in the next version
	Overview the work done by other team members
	Receive and record feedback from team members, UX experts, and clients
	Ensure completeness and coherence of the prototype
High-fidelity prototype	Record decisions taken based on the usability evaluation outcomes
	Retrieve artefacts and decisions generated in previous phases
	Ensure consistency
	Not useful during the face-to-face workshop

Table 11. Overview of the students' self-reported usage of Helaba during the different stages of the UCD process.

The table above gives a sense on the different activities reported and how they evolved through the user study from a more static repository to a place for discussion and traceability. To answer the question of *what characteristics are required in a system to facilitate traceability*, we discuss our findings based on the design guidelines that were used to create Helaba: *support artefact-based communication*, *gather feedback in a shared workspace*, and *enable awareness of artefact evolution* (see Table 9).

6.5.1 G1: Support Artefact-Based Communication

The first guideline indicates the need to have a *visual connection between artefacts and communication related to the artefact*. We explored this guideline with the *Notes* feature of Helaba. Notes are digital post-it notes pinpointed to a specific part of an artefact. We found that the Notes were used to build a narrative of their design process, especially in relation to how artefacts linked to each other. The value of the Notes reported by participants was to record the content generated during their design work. They reported that the content included information about design alternatives and choices. Information regarding the process associated with their design work was recorded to a lesser extent, for instance tasks to be undertaken by each team member. Recording the content and process helped participants to build a narrative of their project. They mentioned that this narrative was easy to record, since the Notes did not impose a structure nor constrained their way of thinking. The students reported to record the following content using Notes:

- Agreements reached,
- Rationale of design choices,
- Next steps to iterate an artefact, and
- Discarded design alternatives.

When it comes to traceability, the narrative built using Notes facilitated the documentation of the rationale of their design work (e.g., what was done, by whom, and why). The teams mentioned that the content recorded in the Notes reveals mostly convergence moments. Similarly, participants did not use Helaba to discuss their designs directly, but to record the topics and outcomes of their discussion. We illustrate this finding with a quote by T1 during the *task analysis phase*: *"We selected [to document] the discussions that we thought that were important for the further design and the progress of the project*."

Divergent ideas were discussed either face-to-face or using synchronous communication tools, such as Facebook chat or Skype. Moreover, even though Notes are enabled as conversation hotspots (e.g., for asynchronous communication), we found a limited amount of conversations – only 24% of Notes had a conversation attached. Participants preferred using familiar communication

tools (e.g., Slack or Facebook chat) and recording the outcome of their conversations into Helaba. This strategy relates to the well-documented fact that recording design rationale can be overwhelming (Horner & Atwood, 2006), as reported by T4 during the *task analysis phase*: *"We recorded some [discussions] on Helaba. However, since we discussed a great amount of it through Skype and face-to-face, it would be double work to add all what was said to Helaba."* Thus, participants selected consciously what particular discussions that took place in another channel they would record.

To evaluate the perceived utility of Helaba to capture design discussions, we asked participants about the type of information they registered in the system, how they registered it, and how often they recorded their team discussions. Participants reported that most of these discussions were recorded as Notes, and included a mixture of design alternatives, decisions, and upcoming tasks. The answers of participants, illustrated in Figure 30, show the proportion of discussions that students perceived to record (as Notes) across the different phases of the study.

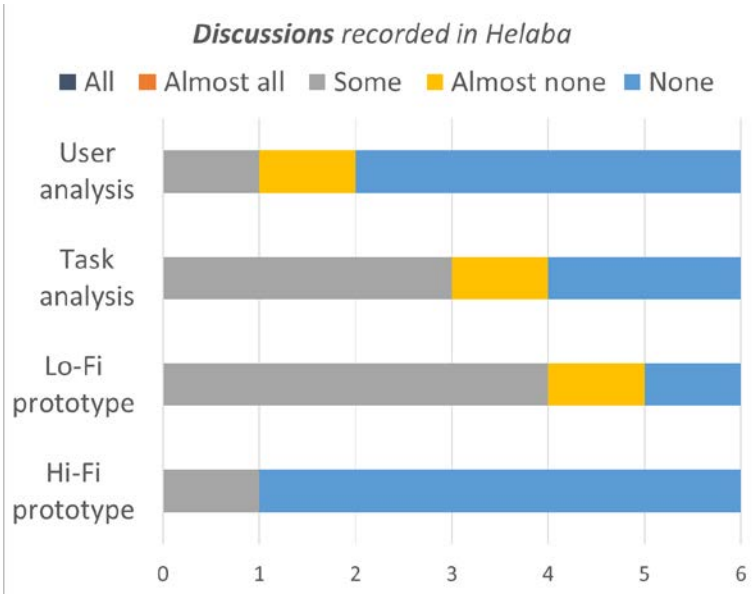

Figure 30. Responses to the question: "How much of your team discussions during [phase] were recorded in Helaba?" mapped to the different phases of the UCD process.

During the *user analysis phase*, four teams did not record any Note. The reason given by these teams for not creating Notes was that their conversations took place in a different setting (e.g., face-to-face or other tool), and it seemed redundant to add their discussions to Helaba. However, there was a shift in the usage during the *task analysis and low-fidelity prototype phases*, as most teams added Notes actively. This finding shows that Notes were especially useful during convergence moments. In other words, where more dialog was required to create an artefact, more Notes were included to record their agreements.

6.5.2 G2: Gather Feedback in a Shared Workspace

The second guideline points out the need for *sharing and receiving feedback from team members and stakeholders of the project in a shared workspace*. We explored how Helaba facilitates traceability with a shared workspace organized around artefacts. Through the shared workspace, we found that teams used the system to gather feedback at two levels: *internal feedback* and *external feedback*.

Participants reported using Helaba to record feedback when working in a remote, asynchronous settings. This type of content was added to clarify or give feedback about the work done by the other team member. Thus, we refer to it as *internal feedback*. Notes were mostly used to record internal feedback, as they allowed pinpointing a comment to specific elements of the artefacts. For example, Student A uploaded a new version of an artefact, and added Notes to let Student B know what changes were made and where. In response, Student B added comments to these Notes to either accept the changes or give feedback about them. See an example of one of such conversation thread between students in in Figure 31.

Teams used the shared workspace actively to receive or record *external feedback*, which included remarks from clients, UX experts, and end-users. All teams reported discussing the feedback from external sources, and recording the outcomes that were used to guide the next iterations. Having a centralized space for capturing feedback from externals was especially relevant in the late stages of the project, when the feedback gathered was used to retrospectively describe design choices (e.g., write final report and defend choices to clients). Making decisions in line with knowledge generated throughout the project was facilitated by having information about previous stages and a log of “what others said.” For

instance, this log was used to reflect on how the contribution of the stakeholders influenced the design process, as stated by T2 during the *low-fidelity prototype phase*: *"The discussions we had [with the client] were added to the artefact."*

Figure 31. Example of a conversation thread added by students in Helaba.

We used the shared workspace for gathering feedback by asking the UX experts to use Helaba for conducting their usability evaluations. A total of 465 Notes were created in the scope of these evaluations. Around 10% of these Notes included a direct conversation between the teams and the UX experts to either clarify feedback or ask follow-up questions. These are more Notes and conversations than in any of the phases of the design process (see Figure 29).

UX experts and students focused on documenting enough information to make the evaluation as comprehensive and useful as possible. During the interview, all the UX experts mentioned that Helaba was useful to understand the design choices of students, as they were contextualized with previous artefacts and alternatives explored. This information helped the UX experts to grasp the struggles of the students and come up with meaningful feedback. Interestingly, after the usability evaluations took place, all teams reported accessing the comments of the UX experts frequently to guide their work. These findings indicate that having a centralized record of artefacts and their rationale can be

useful for both externals and designers to overview in an easy way previous design choices and their feedback.

6.5.3 G3: Enable Awareness over Artefact Evolution

The third guideline specifies that teams need to *maintain awareness over artefact evolution and previous design decisions*. We explored this guideline with the *Lean Repository* and *Decision Cards* features as they enabled participants to capture, retrieve, and revisit information from key points of the design process. For instance, as explained by T3 during the *high-fidelity prototype phase*, participants used the information recorded to inform the next steps of their design work: *"[We used Helaba to] check on decisions/Notes on low-fidelity prototypes and to make decisions on how to create/design the high-fidelity prototypes."*

Lean Repository for Coherence and Consistency

All teams consistently mentioned that Helaba was useful as a repository to overview their project evolution. One of the strong points of our tool for participants was being able to organize different artefacts and versions together with annotations and decisions. This facilitated traceability, as it enabled participants to retrieve artefacts and their rationale, make connections between different artefacts, and iterate them in a coherent way.

The structure used to organize artefacts within Helaba was similar for all teams. For instance, the tasks created by participants were consistent with the stages of the UCD process: all teams had a specific task for each of the phases, with the exception of two groups who did not uploaded their high-fidelity prototype. The pre-defined structure (i.e., projects, tasks, and artefacts) allowed participants to organize files in a more intuitive and useful way than with other file storage services, such as Google Drive. The reason for this increased usefulness was that uploading artefacts together with annotations facilitated awareness of the changes done by others, as stated by T4 during the *high-fidelity prototype phase*: *"If it was useful to put [an artefact] on Helaba for the team partner. Especially if not all changes were discussed or approved by the other."*

To find out how participants selected what artefacts to upload (or exclude) and why, we asked them to report the proportion of artefacts that they uploaded in

each phase. As illustrated in Figure 32, the participants uploaded a considerable proportion of artefacts created during the different phases of the design process. The increased amount of artefacts uploaded during the *low-fidelity prototype phase* could reflect that participants became more proficient in using our tool, but also that more artefacts were created.

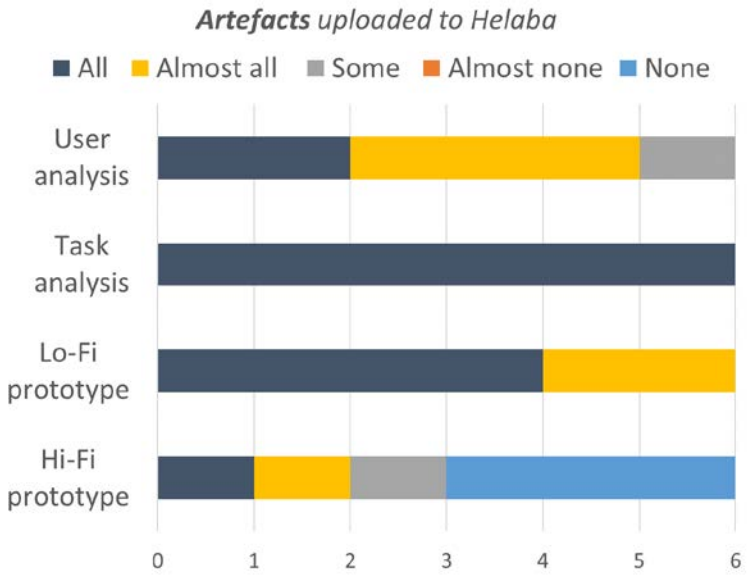

Figure 32. Responses to the question: "How many of the artefacts you created for [phase] were recorded in Helaba?" mapped to the different phases of the UCD process.

We asked participants which version(s) of their artefacts they uploaded and why. Participants mentioned that they uploaded (or updated) a version of an artefact to Helaba when: (1) a new screen was added to the system, (2) a milestone where they reworked a screen thoroughly, (3) an artefact whose direction changed in a significant way, or (4) a finalized deliverable. Keeping a record of a variety of versions of artefacts facilitated tracking changes and their rationale over time. However, try-out versions and those with minor changes were not included in Helaba. This can be related to the fact that participants considered early versions of artefacts as *raw documentation*, and uploaded to Helaba only those that were *formalized* (as defined in Section 2.4.3).

Decision Cards for Consensus and Milestones

The Decision Cards were useful to externalize team consensus in an explicit way. A core strength of Decision Cards is that they supported teams to capture the agreements that emerged from their discussions, without influencing the reasoning process. This result is consistent with the reports of the workshops conducted with design practitioners reported in Chapter 5. In comparison to the Notes, participants felt compelled to reflect upon their design choices before creating a Decision Card. In this way, while participants did not feel "forced" to record or address each of the decisions, they were cautious of what content they externalized as a decision. A reason for this is that consensus is not simple nor easy to articulate. Thus, participants created Decision Cards only to capture what they perceived as a milestone in the process, as mentioned by T6 during the *task analysis phase*: *"We only made a Decision Card of the hardest problem."*

When prompted to explain what information was recorded as a decision, participants mentioned that they captured in Decision Cards those decisions that:

- Were perceived as major and difficult;
- Involved several steps to be executed;
- Involved reworking large parts of the artefacts, such as entire screens;
- Documented intensive discussions or unknowns;
- Included ideas to be explored in the next versions of the artefact;
- Resolved external feedback (i.e., comments from UX experts or clients); and
- Had a larger impact on the overall design.

We asked participants to report the proportion of decisions recorded in Decision Cards during each phase of the UCD process. The responses to this question, depicted in Figure 33, confirm that participants recorded a conservative proportion of decisions. For instance, four teams did not create any Decision Card for the *user analysis phase*. However, these responses also show an increased interest in the Decision Cards for design activities where team consensus is required to create a determinative artefact, such as in early prototyping phases.

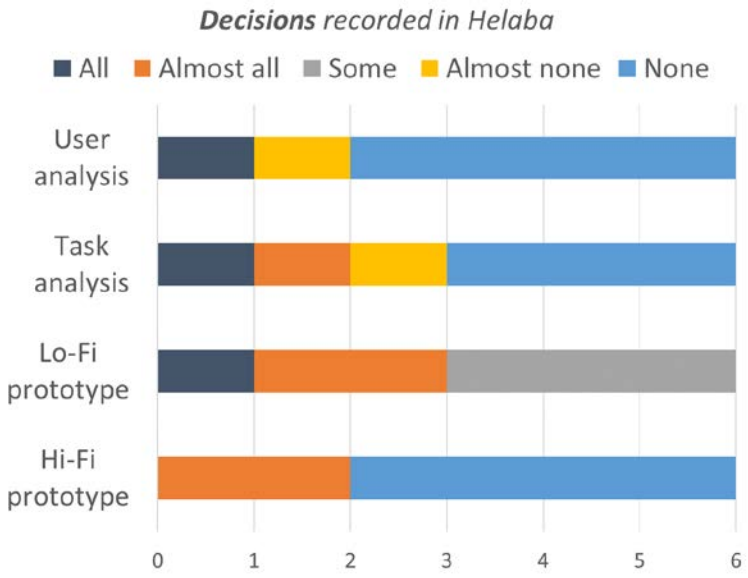

Figure 33. Responses to the question: "How much of your decisions [per phase] were recorded in Helaba?" mapped to the different phases of the UCD process.

Decisions that teams perceived as minor remained implicit, or these decisions were kept as Notes. Thus, Decision Cards are conscious reflections about the challenges and milestones of the ongoing design process. Having a combination of features to record annotations (Notes and Decision Cards) led the participants to consider Helaba as a "repository of decisions." What is more, the participants felt motivated to keep track of decisions for traceability, as expressed by T6 during the *high-fidelity prototype phase*: *"We wanted Helaba to be an extensive database of all our decisions [for this phase], so we recorded all of them*."

6.6 Aspects to Support Traceability in Creative Design

The way participants engaged with Helaba helped us to identify three core aspects to facilitate traceability in creative design: *make and revisit a design narrative, display curated design artefacts,* and *integrate team contributions*.

6.6.1 Make and Revisit a Design Narrative

Consistent with guideline G1, we introduced a flexible, artefact-based approach to document design rationale. Participants created narratives for the artefacts,

"telling their story" throughout the different steps of the UCD process. These narratives situated an artefact with respect to the *content* it reflected, as well as the *process* that led to its creation (Stempfle & Badke-Schaub, 2002). Consequently, all narratives included information about the design knowledge (e.g., design rationale and decisions) and teamwork coordination (e.g., to-do lists).

The flexibility of Helaba helped participants to implement their own workflow within the UCD process, as we intended to when designing the system. All teams applied an iterative working style, as is suggested by the UCD process. Helaba was used to structure and capture the subsequent iterations of their work, and helped them to gradually evolve artefacts. The collection of previously documented knowledge became increasingly valuable for participants towards the end of the project, especially when they had to motivate their decisions to both the stakeholders and the educational team.

Two features were used for creating the narrative: Notes and Decision Cards. The Notes served as a diary for the project to document design knowledge associated with artefacts and convergence moments. As described by Lindley et al. (2013), we found that annotated artefacts enabled participants to engage with artefacts in a meaningful way, and to communicate this engagement to others. The participants considered the Notes as the core feature to make and contextualize the narrative of their design process. The reason for this is the strong association between Notes and artefacts, and the level of freedom that they provide to record information. The Decision Cards were considered more suitable to record milestones in the project, but were less essential than Notes to build the narrative. Decision Cards are also useful to reflect on and articulate team consensus: teams often used them to capture important steps that have a significant influence on the evolution of the artefacts.

The narratives created by the participants act as "emergent boundary objects", as proposed by Dalsgaard et al. (2014). In contrast to the original conception of boundary objects, the *emergent* characteristic indicates that they are "dynamically being transformed in collaborative practices" (Dalsgaard et al. 2014). In this sense, the narratives are transformed across the different phases

of the UCD process. Furthermore, the narratives aid to record temporary ideas, which help concrete concepts to emerge in collaboration with others (i.e., team members, clients, and UX experts). Recording and being able to trace these emergent boundary objects is useful to reflect on the process (e.g., why a decision was taken or when a concept emerged), and to justify decisions during and at the end of the project. This is especially relevant when projects involve a wide variety of Communities of Practice.

6.6.2 Display Curated Design Artefacts

Design activities typically produce a large quantity of artefacts, which has only increased because of the relative ease of creating digital ones (Sharmin et al., 2009). We found that instead of just uploading every source of inspiration and artefact to Helaba, participants selected those that they considered meaningful to represent their process. In this way, all teams used the shared workspace to display a "curated" selection of the artefacts, which represented milestones shaped by team interactions.

The Lean Repository of Helaba serves as a canvas to organize the artefacts that are representative for the design process. Accordingly, participants used this feature to populate a coherent, albeit simplified, visual narrative of their process. Similar to previous research (Lindley et al., 2013; Sharmin et al., 2009; Swan et al., 2010), we found that participants were more interested in reviewing the work of others to become aware of their actions, than in revisiting their own work. Having a curated selection of artefacts is useful to ensure consistency and coherence in the process. Participants knew that the content in Helaba was relevant for both their team and the process. In combination with the narrative, curated artefacts help to build a cohesive story of the project milestones over time.

In this sense, as stated by design guideline G3, it is relevant for the success of the projects to enable awareness of the artefacts' evolution among the team members. We believe that having a designated space to record the relevant "turns and twists" of the design process is useful to visualize the co-evolution of problems and solutions. Being able to select those moments to record (e.g., not enforcing the kind of artefacts or content to record), helped participants to record the

“bursts of development” (Dorst & Cross, 2001) and milestones of the project, which is vital knowledge to produce and record when it comes to traceability (Matta et al., 2001).

6.6.3 Integrate Team Contributions

Design guideline G2 highlights the importance of gathering feedback in a shared workspace. Including the point of view of different team members in a single workspace was a key aspect to support traceability during our study. We did not design Helaba to replace existing established communication tools, and as such, day-to-day communication happened in channels other than Helaba. Discussions happened most of the time in a face-to-face setting, with team members being present in the same location, or discussing issues using tools such as Slack or Skype when collaborating remotely.

However, the shared artefact-centered workspace offered each team the tools to stay up-to-date about the work of each other. Participants collaborated in the system more actively in those phases where more dialog was required to reach a solution, where the problem spaces were larger, and where more unknowns needed to be explored. By reviewing the work of others, participants engaged in an ongoing reflection, which helped them to think on solutions based on the content recorded in Helaba. Furthermore, the design knowledge they recorded helped them to frame their work for reflecting on previous agreements and ideas (e.g., retrospective thinking), and finding new courses of action (e.g., prospective thinking).

The limited amount of discussions and conversations that were recorded put forward the question of whether Helaba (or similar tools) should include different sorts of communication channels, such as chat, video, and conversation threads. We argue that in a tool like ours, recording the design process must remain pivotal. The strength of the system was not that all conversations took place in there, but that it brought together different actors in one “designated” space to discuss and document crucial aspects of the design.

This finding reflects on how the commercial, off-the-shelf tools to support remote, multidisciplinary design work, as described earlier in this chapter (Section 6.2.5).

We believe these tools would benefit from features that help to record and scaffold the design process, instead of being comprehensive communication suits. Furthermore, forcing users to use one single communication tool instead of those already familiar and highly specialized, could result in limiting the acceptance of the system. Traceability is better supported with communication based on artefacts, in a shared workspace where relevant design knowledge is easily accessible. We suggest that it would be interesting to let the user import information from different tools in a seamless way to avoid “double work.” For example, importing a decision that was made in an external chat application into Helaba, rather than copying or typing (again) an entire conversation. This will allow designers to quickly create a curated information flow.

6.7 Conclusion

Recording design rationale is a particularly controversial task given the extra effort that it requires. The minimal structure to upload and comment artefacts in Helaba facilitated creating this record. However, the flexibility in systems such as ours also requires support to warrant that users can add, organize, and retrieve content in an efficient way. In our study, participants decided freely when to record information in the system and the type of information to record in a curated manner. The flexibility and openness enabled by Helaba was fundamental for the participants of our study. Participants captured their design work with the granularity they felt appropriate, and felt free to change directions as required. This is reflected by the fact that participants were able to adapt the tool to their own processes, rather than being limited to strict rules imposed by the system. Assessing the quality or creativeness in the outcomes of the participants’ projects was out of the scope of our study. However, the freedom offered by Helaba allowed participants of the study to focus on the creative aspects of the process, rather than on managing the process itself.

We acknowledge the potential limitations of this study. In particular, we recognize the shortcoming of involving students taking part in an academic course as participants in the study. This could potentially make participants feel they are being evaluated themselves, or that their grades depend on their performance in the study. To reduce this shortcoming, we ensured participants verbally and with

an informed consent that the data gathered would be anonymous and confidential, and only used in the scope of the research study. We systematically reminded students of this fact throughout the study. Furthermore, we offered an incentive with a limited impact on their overall performance (extra half point on their grade (0.5/10)) in order to keep them using the system throughout the 15 weeks of the study.

A second limitation is that a student project, particularly involving Master level computer science students with HCI specialization, could not be representative of experienced designers. We believe this was a valid experimental design in the sense that it allowed us to control the variables, such as timing and design activities. Furthermore, it allowed us to compare and draw conclusions between and within groups. It could be very difficult to conduct a similar study across different teams in a “real-life” professional setting, in consideration of factors such as differences in project specifications, timings, budgets, and intellectual properties. Acknowledging this limitation, we do not claim that these results are generalizable for the entire design practice nor professional settings.

We also found unexpected benefits from involving this group of participants. In our experience, some of these students will graduate to become interaction designers in professional settings, so learning about their processes pointed out ways to better support their educative process, as will be described in the future work section of Chapter 8.

In summary, this study is a necessary step towards understanding how to integrate traceability into the design processes, both in educational and professional settings, where teams have variable sizes and composition. We are certain that Helaba allowed each team to create a narrative of their process that was relevant and valuable for them, both visually and conceptually. Finally, we demonstrated that it is not required to have a systematic or formal approach to support traceability. Thus, this is a significant step towards offering tools that balance formal and creative approaches in user-centered design.

7 Information Recorded as Design Rationale Using Annotations

Design documentation procedures are poorly understood and often debated. We investigate what information is documented by designers in order to interpret the knowledge they find useful, and how it is integrated into their processes. To this end, we continue the description of the data analysis of the same user study that was reported in Chapter 6. In the aforementioned study, we asked six pairs of students engaged in a UCD project to document their design process using Helaba. Afterwards, we analyzed the annotations (i.e., Notes and Decision Cards) generated by the students using a thematic analysis. Results from this analysis showed that participants captured information to surface their design work (*where are we?*) and progress (*where are we going?*). The recorded design knowledge revealed an opportunistic, exploratory, and speculative process. In other words, designers favored documenting a *messy* but creative process, instead of a rational one.

7.1 Introduction

Documenting design processes is recognized as a challenging but potentially worthwhile activity (Shipman & McCall, 1997). When it comes to UCD design, this documentation involves a range of artefacts that embody knowledge that guides implementation tasks. The benefits of documenting the design process are that it demystifies the process, produces a comprehensive collection of design decisions and sources of inspiration, and communicates design outcomes to others (Bardzell et al., 2016; Selic, 2009). In addition, tools for design documentation are used to promote reflection (Dalsgaard & Halskov, 2012; Dalsgaard et al., 2008). However, there is not one single generally accepted approach to create (or teach how to create) design documentation. Moreover, it is unclear how designers can be encouraged to identify and capture relevant information.

Our research is concerned with supporting designers to document the complexities and “messiness” of a UCD process, reflecting on an open and flexible UCD process

more than on a formally structured one. Thus, we explore what information is recorded by designers and how they integrate it into their design process. We aim to encourage novice designers to participate in design activities, and reflect on their design practices, without enforcing a strict approach. For this purpose, we used Helaba as a *communication tool* to provide a shared workspace to annotate visual artefacts with textual descriptions, conversations, and design decisions. Our approach is to capture documentation using a balance between engineering and creative approaches. The pragmatic goal is to use Helaba to understand what designers actually do, and use this information to inspire tool support for documentation.

In this chapter, we report on the same user study as in Chapter 6, as we explore the process followed by six pairs of students during the early stages of a user-centered design project using Helaba as a tool to document their process. Whereas Chapter 6 focused on the self-reported experiences of participants using Helaba, the current chapter focuses on the *actual content recorded by participants.* Furthermore, while Chapter 6 focused on exploring implications regarding the features of Helaba, in this chapter we focus entirely on reporting about the implications for *design communication and documentation*.

It has been suggested that UCD processes should follow well-defined iterative stages, sometimes accompanied by specific notations (ISO, 2010). Nevertheless, it has been acknowledged that design follows an opportunistic approach, and deviates from the plan as required due to the ill-defined nature of design problems (Cross, 2001; Guindon, 1990). In this sense, our results lead to two relevant observations:

1. Creating documentation can be encouraged by using a tool that imposes few constraints on what information to capture, and when documentation is not a strict requirement to move the process forward. The process is steered by the design team, instead of the other way around.
2. Creating documentation should be turn designers into process owners, empowering them to record what they find significant at the moment they find most appropriate. Documentation should not be confined to explain

"generic" design rationales, but serve as an active communication and reflective tool for the team.

According to Cross (1982), the "designerly ways of knowing" should embrace the way knowledge is created in the design process, including its inadequacies, as it reflects on the ill-defined nature of design problems and tasks. The two observations above fit in this designerly approach, where despite using a (well-defined) typical UCD process, the skills, preferences, and creativity of designers are at least as important as the processes.

In the remainder of this chapter, we explore what information was documented within UCD processes. The functional prototype of Helaba (see Section 4.6) was used to capture such information, since it offers a flexible approach on what content to document, how to document it, and to what level of detail. Helaba takes care of creating a shared space for documentation and has all means necessary to link documentation with design artefacts, actors involved, and any phase of the process.

7.2 Related Work

There are multiple perspectives from which to define or approach design documentation. What is deemed as important or appropriate for each perspective largely depends on the underlying assumptions about the design process. As described by Simon (1969), design can be characterized as a rational endeavor, implying that design processes can be formalized and systematized. This position had resonance with software and usability engineering paradigms (e.g., to *measure* usability), which led some aspects of interaction design to be fitted into a "rational" conception of design (Löwgren & Stolterman, 2004; Zimmerman et al., 2007). Conversely, there is growing evidence about the benefits of positioning interaction design as a creative process (Fallman, 2003). Thus, capturing UCD projects should balance between supporting "good practices" in software documentation and accommodating the unconstrained nature of creative work. We built on previous research from both engineering and creative design perspectives to explore ways to support design documentation.

7.2.1 Engineering Design Perspectives

From an engineering design point of view, authoring comprehensive design documentation (e.g., design rationale notations) or the lean and bare minimum (e.g., agile) have been proposed. This points toward a large span of approaches to creating design documentation in the context of interaction design from an engineering perspective. As we are interested in exploring systematic ways to capture design information, the argumentative perspective on design rationale offers an answer this aspect.

This perspective aims to *improve* the quality of design outcomes by structuring the reasoning process of designers (Shipman & McCall, 1997). This is often done by framing and solving problems using semi-structured notations integrated into tools. Below we summarize relevant examples of these notations, which are described in full in Section 4.2: (1) the QOC notation, that represents questions, options, and evaluation criteria for assessing the options around an artefact (MacLean et al., 1991); (2) the IBIS notation that associates design problems with their possible solutions and tradeoffs, and is graphically represented with the gIBIS tool (Conklin & Burgess Yakemovic, 1991); and (3) SIBYL, which supports a team visualization of knowledge by extending the QOC and IBIS notations to support knowledge visualization during the decision-making process (J. Lee, 1990).

While these tools and notations offer valuable insights into how to facilitate the decision-making process and to exchange information to reach a consensus, they impose a structure on design thinking, which can be cumbersome for designers (Burge, 2008; Horner & Atwood, 2006). Thus, documentation is often out of date or incomplete. Furthermore, one core limitation of these approaches is the assumption that design issues are to be solved, instead of part of a space to be reflected upon.

7.2.2 Creative Design Perspectives

From a creative design point of view, design documentation should articulate knowledge that motivates artefacts. Nevertheless, the notion that design is unruly and chaotic implies that standardized documentation is unrealistic. More open

documentation forms are being explored within the research through design approach, where design artefacts are associated with motivating knowledge. Design artefacts in RTD reflect on the rationality and process followed to create them, as they are used to communicate research concepts and theories (Pierce, 2014). Thus, while design artefacts constitute, construct, and contain knowledge, this must be explicitly articulated (Pierce, 2014).

A number of tools and conceptual approaches have been proposed in RTD to link artefacts and their associated knowledge in a way that makes it appropriate to communicate outcomes to a wider audience. Dalsgaard, Halskov, and Nielsen (2008) introduced a tool which uses maps to structure and visualize the interrelation between elements of inspiration material and ideas emerged during the design process. Similarly, the *Project Reflection Tool* (PRT) was used to document design projects with the objective of promoting reflection and discussion (Dalsgaard & Halskov, 2012). Gaver (2011) suggests *design workbooks* to document design proposals (as opposed to final designs) to capture ideas, approaches, and inspiration for a given design process.

In a similar way, Gaver and Bowers (2012) introduced *annotated portfolios* to document the functional and aesthetic aspects, motivations, and practicalities of design. In contrast to design workbooks, the annotated portfolios express the rationality of an artefact by linking it to annotations and other artefacts in an organized way. The annotations are a “textual accounts of partial views onto the design as a whole” and are useful to point what is new and valuable for the research community (B. Gaver & Bowers, 2012). Thus, artefacts and annotations rely on each other to create significance within the design process.

Bowers (2012) suggests that a limited rationality can be created by linking artefacts with (textual) annotations pointing to relevant matters for the research community. We are inspired by this work, which values not only final artefacts, but also generated knowledge, which it seeks to capture in an organic way. The value of these solutions is that they integrate the creative, progressive nature of design, and avoid constraining the thinking process of designers. As with these solutions, we aim to explore design work while respecting the existing practices of designers, and avoid imposing a structure to it.

7.3 Methods

The methods applied in this user study are largely the same to those reported in Section 6.4. We asked six pairs of students to record their UCD process using Helaba for a period of 15 weeks. Additionally, three UX experts with an average of 7 years of experience in HCI research joined around the mid-point of the academic course to evaluate the usability of low-fidelity prototypes created by the students. The participants, design assignment, phases, and activities of the project, as well as the experimental design, are identical to those reported in Chapter 6 (Sections 6.4.1 – 6.4.3). Thus, the reader should refer to these sections for the full details of these aspects of the user study. In contrast with the data reported in Chapter 6, we now focus entirely on the content uploaded in Helaba. In other words, we used the annotations added to Helaba (i.e., Notes and Decision Cards) as raw data, which was analyzed with a thematic analysis.

We created a matrix to map all the generated annotations to the artefact they are associated with, the stage of the process in which they were created, who created them, and the attached conversations when applicable. Our analysis focused on the textual annotations generated by the students and UX experts rather than on the quality of the visual artefacts. We made this decision as the quality of the artefacts is more likely to be related to the skills of the students than to the process followed (Stolterman, 2008). Furthermore, its evaluation could be highly subjective, as the requirements and focus of the prototypes were defined by each team.

7.3.1 Data Analysis

We carried out a qualitative analysis of the annotations generated by the participants during the longitudinal study of 15 weeks. An important part of this task was conducting a thematic analysis to identify and report the data patterns. As suggested by Braun and Clarke (2006), we used thematic analysis to find patterns across the entire data set using an inductive approach.

At the beginning of the data analysis, each of the annotations we gathered was assigned to a set of initial categories according to the information it contained. For instance, if a Note described a feature contained in the UI, it was categorized

as “UI element.” This analysis was done across the content generated by all the student teams. The initial categories were revisited, grouping those that seemed to be repeated or related. At the end of the analysis, 12 categories were defined. These categories, detailed in Table 12, were high-level descriptions of the content written in the annotations, which revealed recurrent kinds of recorded design information.

Topics	*Categories*
What?	Consensus, Question, Argument
How?	Instructive, Evaluation
Where?	UI elements, Interactions, Artefacts
Why?	Facts, Value, Inspiration, Process

Table 12. Coding categories organized in four core topics.

The content of an annotation covered between 2 and 9 categories, according to its length and the complexity of the information included. For instance, those Notes that had conversations spanned more categories than those that only included a few keywords. Since our principal focus was on understanding the design information that was documented by the participants, we clustered the 12 coding categories into four core topics according to their goal (see Table 12). Each topic represents one aspect that can be covered by documentation, and together the topics cover the full spectrum of explanation that is covered by the documentation. These topics and their categories are not absolute: they overlap and blend as each annotation usually covers one or more topics. For instance, a single annotation could present an explanation for including (*what?*) a certain element of the UI (*where?*) using a design guideline (*why?*). Thus, these categories interlinked and formed meanings together.

The *What?* topic included annotations which indicated that *consensus* was reached. In other words, that an agreement was explicitly mentioned in the annotation. *Questions* included direct inquiries made by participants to others,

and *arguments* were used to describe a certain design element or choice. The *How?* topic included *instructive* annotations, which expressed how a task was to be executed, and *evaluations* that explained criteria to measure failure or success. The *Where?* topic included statements about *UI elements* to describe a feature of the application, *interactions* (e.g., how someone would use the system), and annotations that referred to another *artefact* created (or to be created) during the process. Finally, the *Why?* topic referred to *facts*, which are concrete knowledge gained during the design process, *sources of inspiration*, and perceived *value* for a certain design choice. Also general explanations on how their design *process* gave direction within the project were included in this topic.

7.3.2 Applying Resource Functions Analysis

In addition to the open coding that was performed using thematic analysis, a complementary analysis used a closed coding scheme based on the *resource functions*, which provide "a vocabulary that supports understanding, assessment and improvement of existing design and evaluation approaches" (Cockton, 2013a). Initially, resources were seen as having types, based on their main function (Woolrych, Hornbæk, Frøkjær, & Cockton, 2011), such as *scoping*, *expression* or *instrumentation*. However, applications of resource analysis to design practice (Cockton, 2013b; Garnik, Sikorski, & Cockton, 2014) revealed that resources have multiple potential functions, which could be activated sequentially or concurrently.

Ten such functions were identified in previous research (Cockton, 2013a, 2013b): *scoping*, *valuing*, *asking*, *directing*, *expressing*, *informing*, *performing*, *invigorating*, *protecting*, and *integrating*. Four further functions have been identified in further analyses of design work: *ideating*, *reflecting*, *deliberating*, and *affiliating* (strengthening team bonds). Fourteen functions were thus available as a critical lens to complement the themes that emerged from the thematic analysis. These were applied to look for behaviors and practices that had been overlooked or underappreciated in open coding. The expectation was that the functions would identify resources that were critical to design work, but not recorded as specific annotations within Helaba, and thus expose some dynamics of students' design work, especially design moves and the reasons for them.

7.4 What Design Information Was Documented?

A total of 688 annotations were produced by both students and UX experts during the study. From this total, 223 annotations were generated by students, and the rest by UX experts. A total of 85 of these annotations contained comments (i.e., a conversation thread). The initial analysis revealed few differences between Decision Cards and Notes (with or without conversations). In general terms, Decision Cards contained decisions, but there were also implicit decisions in Notes, or descriptions about the user interface elements in the Decision Cards. Therefore, our analysis thus considered both sources of annotations together.

We found that the bulk of annotations talked about the UI design aspects of the project, with only one or two talking about details of the implementation. This finding can be influenced by the fact that the UCD process followed by students does not focus on architectural software design and detailed programming, but stops at the interactive prototyping stage. Thus, it might be less useful to discuss technical details. However, this also suggests that students were mostly interested in recording and discussing UCD concerns, even when given freedom to include technical details. At the highest level, we found two overarching types of recorded information: *exposing design work* and *exposing design progress*. In the sections below, we explore dependencies between the categories and resource functions that support them. We present evidence of these findings by adding quotes of the different students (SP1 – SP12), teams (T1 – T6), and UX experts (EP1 – EP3) involved.

7.4.1 Exposing Design Work

The first type of annotations included a retrospective of the work done in order to evolve a design artefact. In a broad sense, these annotations were a response to the question “where are we?” by providing snapshots of the design process. Participants pointed to *how* and *why* they arrived at certain design choices by *making sense of the design process* and *describing the pool of ideas explored*.

Making Sense of the Design Process

Annotations were used to justify, rationalize, or *make sense* of design work. Students often articulated the benefits of certain design choices using their “gut

feeling." They seldom included facts about end-users or sources of inspiration. The annotations that reflected their best judgement or intuition were explicit, as the students often mentioned uncertainty about a design alternative, but justified it using the perceived value. This is shown in a Note created by T1 during the *low-fidelity prototype phase*: "*We selected both text and icons in the menu bar buttons. Especially for people with less computer knowledge, the text is important."*

This kind of annotations were frequent in the *low-fidelity prototype phase*, as students surfaced their choices, and tried to explain why a certain change should be made. Annotations which included facts about the end-users to make sense of the design process often expressed consensus. This is the case of a Decision Card of T1 written during the *user analysis phase*, where they refer to the initial interview with a representative end-user of the application: "*We decided that the new design […] should guide the user more through the different fields, for example by a wizard style. The interviewee also suggested this."*

The most frequent source of inspiration was the current version of the application being re-designed, as students used it to clarify why a certain decision was made. We illustrate this with a conversation (recorded in a Note) between SP12, a student who was member of T6, and the EP3, the UX expert who evaluated their prototype:

> EP3: *When entering an amount, there may be confusion about decimal places […]. How should a decimal number be entered […]?*
> SP12: *[The current system] first converts all points to commas before validating the field, we thought the same approach would be used unless the client asked for something else.*
> EP3: *OK.*

In the quote above, the students used the clients as a reference to frame the design process, and to open the possibility of "reframing" the solution if it was requested by them. Sources of inspiration and facts were mostly documented in the *high-fidelity prototype phase*, as there was a clearer direction of the final design and engagement of end-users and clients.

The UX experts were more likely to provide factual information and sources of inspiration to back up their comments. For instance, more than 30% of the

annotations created by the UX experts included information about the heuristics or design patterns used as evaluation criteria, compared to fewer than 20% of the students' annotations. This finding reflects on the fact that the UX experts had a more extensive vocabulary, knowledge, and experience to talk about UI design and usability. Furthermore, the role of the UX experts was to evaluate the artefacts produced by the students, which meant that they had to point out specific guidelines and evaluation criteria. Expressing the benefits of specific design choices within annotations involves an ameliorative resource function (Cockton, 2013a), as the benefits (ameliorative = making better) are used to make sense of the design choices selected, and offer a more complete and accurate rationale for design elements.

Recording a Pool of Ideas

Only 34% of annotations added by students included a concise description of design decisions. We found that all the Decision Cards captured during the user study included decisions, but also Notes were used for this end. Nonetheless, the overall majority of annotations were used to describe elements of the system without signaling consensus or agreement. Some of the alternatives explored and recorded could potentially have been turned into decisions made "outside of" Helaba, and passed in an implicit way to the next version of the artefact. However, it is clear that students frequently recorded unsuccessful ideas or topics that were not further explored. Thus, the pool of ideas included a backlog of preliminary ideas that documented incomplete knowledge acquired during design work. These annotations surfaced incomplete knowledge, (risky) assumptions, and hypothetical situations.

Conversations associated with the pool of ideas articulated incomplete knowledge, a lack of consensus on ideas, or flagged potential design issues. We illustrate this with a conversation by T4 during the *high-fidelity prototype phase*:

> SP8: *Removed the save button as logout was already available in the background.*
> SP7: *Sure? Thinking that many people save their work first before signing out, because they want to continue with it another time.*

In the conversation above, we have clear indications about the element being discussed (e.g., the save button) and reason for the discussion (e.g., discarded

or kept). However, there is no follow-up in the annotations to indicate what its resolution was.

Besides open design choices and argumentation, students created a pool of ideas with descriptions about the UI to clarify its content. This was frequently done during the usability evaluation, as students aimed to explain to the UX experts why a certain decision was made, and how a user would interact with the system. This is illustrated with a Note added by T3 to clarify to a UX expert the interactive aspects of an (static) artefact: "*The user will see a list of items that must be filled in to send the declaration. [...] You can navigate between sections with the two top buttons."* Furthermore, annotations related to the pool of ideas were used to scope the project. For instance, by clarifying why a part of the prototype was not elaborated on further, as written by T4 in a Note during the usability evaluation: *"The other buttons are not worked out in the prototype; because they are out of our focus."* These annotations reflect the "expected audience" of the artefacts (i.e., UX experts or fellow students), which aid understanding their rationality.

The pool of ideas was also enlarged by the UX experts, who offered thoughts for students to either follow or discard. Around 60% of annotations contained conversations between students and UX experts that resulted in explicit consensus on the next steps for the application. This was clear when students confirmed that an action would be taken as a response to comments from a UX experts, such as the next conversation that took place in T1 during the *low-fidelity prototype phase*:

> EP1: *Is this the only way to navigate back to previous sections? […] I do not see a button to return to the main screen.*
> SP1: *The button at the top returns to the main screen. We will also add a button in the right part to return to the previous section.*

An obvious concern of creating documentation that includes a *pool of (often discarded) ideas* is that it could make difficult to reconstruct a full rationale, which might require a complete elaboration of all ideas explored, and the arguments for accepting or discarding them. Lacking such record could lead to have partial design rationales, which might be undesirable from the argumentative design rationale perspective (Shipman & McCall, 1997). However, a benefit of these "fragmented rationales" is that they recorded ideas that could potentially be lost,

even if not completely elaborated or left open. These annotations in the pool of ideas relate to the *adumbrative* function that delineates the scope of the design project, the *inquisitive* function, which questions about relevant information, the *expressive* function that externalizes information and the *performative* function that "spreads" information in a form appropriate for its audience (Cockton, 2013a).

7.4.2 Exposing Design Progress

The second type of annotations included information about the dynamics for moving design work forward. These annotations gave a sense of direction to the project by answering the question of "where are we going?" They were frequently exploratory, as participants *envisaged use* and *framed the design space*.

Envisioning Use

The annotations for envisioning use represented the "what if?" of the design process, such as whether a UI element should be added, modified, or discarded, and the impact that such change would have. This is illustrated with a Note by T3 during the *low-fidelity prototype phase*: *What I really miss is a visualization of the progress of the section. If it is not visible, […] the user can wonder how long it will take. A proposal: include the progress bar at the top […].* Interestingly, the "what ifs" were frequently explored by participants with partial use cases, as they envisioned the sequence of steps that the end-user would follow when using the system. In this way, the partial use cases served to imagine how interactions would happen, which in turn helped to generate and evaluate alternatives. By reflecting on how a particular user would engage with the interface, participants were able to detect potential flaws in the design.

In most cases, these annotations for envisioning use were left open, with no clear indication on what choice was made, as the decisions were left implicit in the next iteration of the artefact. However, some of these annotations signaled consensus, as participants explicitly articulated the next activities to be undertaken. We illustrate this with a Note created by T5 during the *task analysis phase*: *"Create new layer for the tabs so the user can select different 'sections' […]."* These annotations served as a bridge between implicit and explicit documentation of

needs that emerged during the design process. By mentioning tasks to be realized (e.g., changes to be implemented), Helaba became a resource for managing team activities. Expressing consensus enabled task awareness, as it made division of activities evident.

The resource functions (Cockton, 2013a) related to envisioning use are the *expressive* and *directive* functions that articulate and guide design respectively. Furthermore, the *protective* function is used to steer the design "in the right way", and the *integrative* function to merge elements together (e.g., UI elements and interactions).

Framing the Design Space

Annotations that framed the design space included those where participants spotted relevant pieces of information (i.e., aha! moments). These pieces of information were used to refine the direction of the project. This was frequent in annotations where participants detected unknown information, which needed to be addressed. For instance, they narrowed solutions by considering the needs of end-users or clients. This is explained in a conversation of T6 during the *low fidelity prototype phase*:

> SP11: *Should there be two headers (of different sizes) […], or maybe an entirely different approach?*
> SP12: *I think it is good [as it is], we can always ask feedback to the education team / customer.*

Framing the design space helped participants to detect and meet their knowledge needs in an opportunistic, ad hoc way. Furthermore, we found annotations where participants framed the design space by exploring alternatives for future iterations of the application or opportunities for new artefacts. Thus, participants did not limit themselves to working on one artefact (e.g., as defined by the project structure), but framed a larger solution. Through the process, participants opened and narrowed the space for exploring alternative solutions. The framing was also achieved by talking about different artefacts and how they would be impacted in the next stages of the process. The participants were expected to follow a linear process, in which they were not instructed to create another version until each phase was finished. However, they started to envisage how the next iteration could be framed during the previous stage. This reflects how design work on itself

generates alternatives that can be passed to the next artefact. These annotations are in line with the *adumbrative*, *integrative*, and *invigorative* resource functions (Cockton, 2013a), as they outline the design process, and merge design elements together in ways that speeds up progress for design work.

7.5 Implications for Design Documentation

7.5.1 Reflections about the Process Followed by Participants

The core value of documentation came from *reflecting on work done and anticipating usage in context* (e.g., partial use cases and hypothetical user interactions). By reflecting on the work done, designers could take a step back and articulate their work. By anticipating usage in context, designers can detect more easily "surprises" or unexpected elements that could come into play (Dorst & Cross, 2001). The context of use helped participants to frame and reframe their work as necessary, to fit the evolution of both perceived and actual usage of what they were designing (e.g., after talking with end-users or the client).

Maintaining a record of annotations allows solutions to emerge, but also to keep these for future reference. The "surprises" during the design process were recognized as turning points in the creative design process, and were captured in the documentation. Our participants fitted the *reflective practitioner* concept (Schön, 1983), as they reflected on their own ideas in order to find appropriate solutions. Notice that students were not formally trained in creative design, nor were they guided in a particular direction by the course's structure. The act of documenting their work made evident that students followed a creative process, not a rational (or linear) one. We propose that documentation in the scope of UCD projects can be framed within "designerly ways of knowing" to support designers to reflect on their own process and be aware of the "surprise" moments emerging from the co-evolution of problems and solutions (Dorst & Cross, 2001).

The resource functions detected were also relevant to demonstrate that the participants followed a largely creative approach to the design task at hand. Significantly, they were not in a "rush" to find a right solution, but directed their effort to ask the correct questions (*inquisitive* function), to find the value (*ameliorative* function), and record it explicitly in order to create common ground

(*expressive* function). Resource function analysis proved to be useful for contextualizing findings on design practices.

7.5.2 UCD: Between Engineering and Creativity

As expected in a UCD process, participants followed an iterative approach to find solutions. In agreement with previous literature, we found that there was no linearity to the process (Guindon, 1990; Visser, 2009). The students' phases interleaved or even overlapped. For instance, they framed design solutions – in breach of strict sequential phases – for the *high-fidelity prototype phase* during the *low-fidelity prototype phase* if they found a relevant part of information, even if it was ahead of the process. The driver of progress in the projects was very much solution-centric, and participants tended to adapt the process according to their specific needs. Whenever the participants had an "aha!" moment, they integrated it into the design space. It was this process of (re)framing the design space to find appropriate solutions that exposed gaps in knowledge that designers had about users and context of use of the existing system. There was not one initial clear understanding of target user(s), but instead this knowledge was constructed throughout the process. It was only as actual design activities were performed that relevant questions emerged. This is consistent with an opportunistic design approach (Guindon, 1990). When participants got "in the flow" of doing design, and when fine-grained details emerged, they knew *what to ask* and *who to ask*.

Another relevant observation was that knowledge gathered about end-users was not always of central importance for making the design decisions. How knowledge about users is internalized and then extrapolated played a significant role. Actual facts are less used than the designer's perspective on such users in order to rationalize design choices. This is consistent with what was reported in previous research (Friess, 2008): we can also confirm that a vast majority of the design choices of participants were not based directly on user knowledge, but on their interpretation of it. This implies that UCD work is for a substantial part based on the assumptions of the designer. As the project progressed, however, students gradually refined their representations of target end-users and identified, generated, and documented the user knowledge that was still missing. To provide

support in such situations, we argue that documentation should be able to facilitate a non-linear process. Although UCD processes are often well-described, their actual implementation can vary considerably and is highly dependent on the actors involved in such a process.

7.5.3 Helaba vs. Other Documentation Approaches

In Section 7.2 we framed Helaba with *annotated portfolios* and *argumentative design rationale*. In this section, we discuss how our findings were relevant to these approaches to design documentation.

Annotated Portfolios Approach

We framed our approach using annotated portfolios. We found that participants had similar benefits to those reported of using annotated portfolios, such as reflecting on their design choices and linking artefacts with valuable information for the design process (Bowers, 2012; B. Gaver & Bowers, 2012). Having a blank canvas to connect artefacts, annotations, and conversations facilitated participants' reflection on their own process. The value of Helaba for a design process was that it created a social environment, where documentation was created in a "just in time" (concurrent with the process) and lean way (generated only when needed).

A potential limitation of this type of documentation is that it can create an overwhelming amount of information, which would make it hard to form an overview of the process. It could be difficult to communicate with others, or maintain raw documentation (e.g., including unknowns and discarded ideas). Decision Cards were a good way to gather decisions, and could be further explored as a way to generate a "report" from annotated content. This would generate something similar to annotated portfolios to disseminate and communicate the outcomes of the design process.

Argumentative Design Rationale Approach

Our findings suggest that design rationale is composed of "bits and pieces" of information. Partial knowledge was used to form a single idea. Rationales were not expressed in unique statements (or annotations), but were built gradually across different phases of a project. For instance, while there could be a "clear"

rationale for a low-fidelity prototype, this evolved and was enriched by a high-fidelity prototype. Adding pieces of information to make sense of the process, and then talking about it, made it easier to see the rationale and the value of a decision, and the criteria used to eventually evaluate it.

Participants rationalized specific parts of the design and points of the process, not the entire project. This makes a systematic approach such as creating a formal design rationale difficult, as it means that one has to deal with several pieces of missing information. This is in line with what is reported in previous research (Burge, 2008; Karsenty, 1996), where designers are required to have a very active, and possibly overwhelming, role in crafting the rationale as an additional artefact in the design process. Approaches that steer documentation activities in one specific direction (e.g., design rationale notations) could have the benefit of stimulating designers to think about different aspects they would not consider otherwise. However, these approaches could potentially limit exploration and reflection, which are essential design activities.

The documentation that was generated by designers during the process is very valuable since it allowed reflection and triggered further exploration of alternatives. Furthermore, documenting preliminary or rough ideas helped to generate new ones, some of which were discarded in the process, but some of them also grew out to become very valuable solutions. As mentioned, participants did not feel the need to go back and resolve all the loose ends in annotations, so they documented all ideas according to their own preferences. We would also expect that using argumentative design rationale would decrease the number of ideas recorded because of the effort of thinking about all the details. Having a space for conversation was relevant for students and UX experts to generate new ideas in collaboration, more than to create an exhaustive record of rationales.

Is There a Correct Approach to Document UCD Processes?

Our findings indicate that there is not “one correct” way for creating design documentation. It is dependent on the phase of the project, the team involved, and the project itself. However, supporting a designerly approach facilitates identifying relevant information to record, such as reflections on the process and team agreements. Furthermore, we found that a simple approach to record

software design documentation can facilitate recording the intricacies of design work.

By analyzing the content recorded by students, we revealed that UCD design documentation should contain information about both alternatives explored and decisions reached. Participants documented conversations to both *open* the design space for exploring divergent ideas (e.g., discuss alternative layouts), and *narrow* it for converging in a possible solution (e.g., new feature to be included). No static way of documenting the next actions is needed (e.g., to-do lists), but more ways to externalize or clarify agreements on how to move forward with a project.

Documentation is not only about capturing past or future actions, but also about *contextualizing why a certain decision was reached*. There should not be static documentation nor one single space to collect all conversations. Rather, documentation should be able to evolve together with the design process and outcomes, where it takes place, and who is driving it. After all, the delivery of design artefacts generated in a process is seldom the end goal – it is a beginning of a new lifecycle, a next step in the evolution of an artefact.

Having an audience for presenting design outcomes has additional value, as designers must reflect on how and what they want to present, resembling formalized documentation. The same is true for having UX experts engage with students during a documentation process, which prompts reflection on what to present and describe to UX experts. There is immediate value in the documentation by having all information in one place that can help to organize and scaffold the process (e.g., keep users in mind). As with annotated portfolios, the annotations in Helaba were created for different “audiences”, which means that they were shaped in different ways and with different purposes (Bowers, 2012). Furthermore, these annotations were accessible to the other team members (Löwgren, 2013), which facilitated communication about the design process.

7.6 Conclusion

We explored the long-standing, but still present problem of creating design documentation. We were inspired by both engineering and creative design

approaches, and set out to find a more flexible approach to documentation that supports creative design practices. The study presented in this chapter is a continuation of the analysis presented in Chapter 6, where we reported on the opinions of the participants involved in a longitudinal assessment of Helaba. In this chapter, we reported on the analysis of the content recorded by these participants throughout the study. We found that, when provided with an open and flexible approach to create documentation for a set of creative design activities, designers tended to carefully and consciously document their design process.

The results of this analysis, in combination with the findings reported in Chapter 6, make us conclude that a tool like Helaba, with an open approach to document design rationale, can become a reinforcement of design activities rather than a burden. For instance, participants reported that our tool was useful to record alternatives explored, decisions reached, and that it enabled team awareness and coordination. These reports are consistent with the data analysis of the content recorded: participants documented a creative process where they recorded information that they found relevant to progress the project.

Similar to the study described in Chapter 6, this study is not without limitations. The content recorded by students, which is the focal point in this chapter, is likely not to be representative of the content that would be produced by professional interaction designers. Moreover, the UCD project described in this study could be biasing, as it establishes the sort of tasks followed by students. We found that the flexibility enabled by our tool supported different ways of working followed by the students. As such, we would expect that Helaba could accommodate a variety of professional practices. We believe this study is a valuable, pragmatic step towards empirically evaluating the documentation of design rationale in UCD processes, and can be used to inform longer contextualized explorations. For instance, it would be very interesting to deploy our tool in a professional setting, and analyze the documentation generated by designers over a long period of time. Having a larger dataset of annotations (i.e., Notes and Decision Cards) could serve also to refine and complement the categories and topics we detected in our thematic analysis. This direction could, as will be pointed out in the next chapter, be the basis of future research explorations with Helaba.

Part IV: Reflections and Conclusion

8 Reflections and Conclusion

8.1 Summary

This PhD focused on supporting the collaborative work of multidisciplinary design teams. I framed my research borrowing concepts from the fields of HCI, design theory, and CSCW. This allowed me to have a clearer understanding of the designers' needs and practical issues that occur during collaborative activities. I was interested in how interaction designers follow a user-centered approach and communicate with stakeholders from different disciplines. More specifically, I investigated the work practices of these teams, and proposed solutions to facilitate team communication around artefacts.

While the co-evolution of problems and solutions stimulates creativity, its outcomes are hard to communicate (Dorst, 2006). Designers report issues when communicating design solutions to others, especially non-designers; something often due to the lack of a common vocabulary, and the different priorities and interests (Eckert et al., 2005; Stolterman, 2008). Nevertheless, before a design solution is reached, it must be accepted by all relevant actors of the process (Dorst, 2006; Rogers, 2004). Consequently, designers must find ways to communicate not only what a design is about, but also why it is an appropriate solution in the context of a given problem. These challenges were worth pursuing, due to the relevance of multidisciplinary communication, and the apparent lack of support that is reported both by our studies and in previous research (Gutierrez Lopez et al., 2015b; Rogers, 2004; Sharmin & Bailey, 2011).

Additional research is needed to understand the collaborative practices of professional designers and the digital tools that support them (Dalsgaard et al., 2017; Inie & Dalsgaard, 2017; Stolterman & Pierce, 2012). More specifically, this work responds to the lack of appropriate tools for recording design documentation. While design documentation is an integral part of the process, it remains an area that is largely unexplored (Bardzell et al., 2016). Solutions proposed in previous research, such as design rationale tools and notations, remain generally unused

by practitioners since they constrain design thinking (Horner & Atwood, 2006). In my explorations with designers, I found that designers use common tools, such as Dropbox and e-mail clients, which they adapt for creating documentation. In response to these challenges and opportunities, I investigated ways in which documentation could be better supported with technology. My PhD research drew upon the practices of designers and previous research on design rationale and documentation of design processes. With this approach, I attempted to tackle the boundaries for documenting design rationale and at the same time stimulate multidisciplinary communication as well as creativity.

8.2 Reflecting on the Research Questions

The research questions defined in the Introduction chapter are revisited below, with a reflection on the associated contributions highlighting the practical outcomes and the knowledge generated. This is followed by a critical reflection on the overarching approach followed and its limitations, and a description of future work.

8.2.1 Collaborative Practices and Design Documentation

For exploring ***RQ1 – what collaborative practices do designers use to communicate their design outcomes?*** I looked at the collaborative practices of design teams, with a focus on the tools and artefacts that are used to communicate design outcomes. This was done by conducting three user studies, which resulted in directions that point to meaningful ways in which technology could support these practices.

The first user study (Chapter 2 – Section 2.3) explored the *challenges that professional designers face when collaborating in both co-located and remote settings*. This study revealed that designers often face miscommunications when talking to stakeholders remotely. Thus, they invest time in documenting their work in a way that captures the rationale behind artefacts, and that leaves a trace of the interactions. The second user study (also Chapter 2 – Section 2.4), which was a follow-up to the first study, investigated the *practices of design researchers when it comes to documenting design activities*. The findings indicate that design documentation is active and created largely with a communicative purpose and

particular audience in mind. The content that is documented and its level of detail are related to the intended audience and the maturity of ideas. The third user study (Chapter 3) included the *ethnographic observation of six design meetings involving professional UCD teams*. We found that artefacts were used as starting points to trigger design activities, mediate collaboration, and externalize knowledge in a visual way. During meetings, artefacts can be used as input to disseminate and appraise existing knowledge, or as output to integrate a variety of points of view into a shared artefact.

The insights gathered about design practices led to five *design directions* (Part I). As suggested by Sengers & Gaver (2006), these directions point towards design spaces open for exploration. In the scope of this PhD, I put these design directions to practice, and created tools that adhere to these directions in order to support collaborative design practices (Part II). These tools were iteratively assessed, which also served to inform the research process (Part II and III). Below, I detail the design directions, and map them to the tools developed in this PhD.

- **Support visual communication:** Design artefacts are contextualized in daily practice together with their rationale and the conversations that led to their creation. Hence, my approach has been to *investigate digital tools to support communication around artefacts*. In this way, design documentation is created in action and with a defined purpose. In order to support visual communication, I created the Notes and Decision Cards features of Helaba (Sections 4.6.1 and 4.6.3 respectively). The assessment of these features showed that they are useful to create *design narratives*, which in combination with artefacts, help designers to build a cohesive design rationale of their design processes over time.
- **Organize large amounts of information organically:** Designers actively curate what information to record and how to record it. Thus, it would be counterproductive to force them to document design rationale in a specific way. Instead, a solution should encourage designers to build a story, allowing them to gain an overview of their processes, and making it easy to create and retrieve previous knowledge. I suggest using a *shared workspace where artefacts can be organized and contextualized in an accessible way*. This is explored with the Lean Repository approach offered by Helaba (Section 4.6.2).

When evaluated in the context of a longitudinal design process, this repository served as a canvas to organize artefacts, which in combination with the design narratives, served to advance the process by giving teams an overview of the work done and of the next steps in the process.

- **Engage diverse team members with a shared workspace:** Design activities progress smoothly when design teams share a workspace (Dourish & Bellotti, 1992). Such workspaces facilitate teamwork, enable awareness, and focus discussion around artefacts, even when different points of view are involved. I used Helaba to explore *digital workspaces that focus on communication around artefacts* (Chapter 4), and evaluated this tool in ongoing design processes (Chapters 6 – 7). The workspace provided in Helaba was useful as a *designated space for artefacts and rationales, where the participants chose what information to record, and how to record it*. This freedom facilitated to create narratives that depicted a creative process, where ideas explored were recorded openly, regardless if they were discarded or accepted.
- **Include multidisciplinary points of view during design meetings:** This direction advocates for balancing the inclusion of a variety of points of view and contributions, which can promote accountability and shared ownership. People from different disciplines need to *recognize their input and link it to their ideas within design artefact in a visible way*. The information contained in the Decision Cards (what a decision is about, and who was involved in taking it) could support this in an implicit way. Given that Decision Cards do not enforce any particular notation or manner to record decisions, and that their format is simple and intuitive, they could be useful to communicate ideas among different disciplines. However, in the context of design meetings, this design direction was only briefly explored in this PhD, and thus it has to be studied more into detail as part of future work.
- **Recording decisions using visible and tangible artefacts:** The findings from my engagements with design teams suggested that methods for capturing emergent design decisions should have a *low usage threshold, be tangible, and cause a minimum of friction*. Simple yet effective formats to record design decisions can be useful for this purpose. I introduced and

explored Decision Cards as an investigation of these formats in Chapter 5. During their assessment, Decision Cards proved to be useful to keep track of milestones, including *mindful reflections on the decisions* taken by the design teams.

In summary, these design directions and the corresponding design tools help document design processes based on the real practices of designers.

8.2.2 Tools for Documenting Design Activities

One of the overarching goals of this work has been to bridge structured, rigid approaches to capture design rationale, and a new approach that matches the free flow of ideas that characterizes design processes. We build on this goal with ***RQ2 – what tools should we create for documenting design outcomes based on existing collaborative practices?*** This research question is relevant since design practitioners are reluctant to formally record design rationale, as tools for this purpose structure design thinking and constrain creativity and innovation (Burge, 2008; Horner & Atwood, 2006).

In this PhD, I proposed and developed two tools, *Helaba and Decision Cards*, to capture design rationale. These tools are motivated by the idea of creating low threshold tools that can be integrated within existing design processes. I grounded my work with existing research on design rationale and combined it with the insights gathered during the user studies and iterative assessment of these tools with designers in order to propose solutions that match their collaborative practices. I applied a user-centered design approach, where I explored design alternatives, assessed them, and iterated over viable solutions. Consequently, the tools described in Part II of this dissertation have been thoroughly informed by the work practices of designers.

Helaba is a communication tool that provides a shared workspace for teams to integrate communication about design rationale and evolution of artefacts over time. The early assessment of Helaba suggested the importance of offering low threshold and flexible ways to create documentation, as it should be an activity that comes as an organic part of design itself. In addition, this assessment also indicated the need to organize and overview artefacts and design outcomes in a

semi-structured way, in order to manage the large amount of content that is produced and externalized during the design process.

Decision Cards are a low threshold format to capture information about design decisions, including what decision was taken, why it was taken, and who was involved. The studies conducted with designers suggested that Decision Cards are useful to externalize ideas within design teams, and for informing external stakeholders about the design process in a quick way. Designers were willing to adopt Decision Cards mostly because of their potential to provide traceability of the evolution in long-term design projects.

By exploring the aforementioned solutions, I demonstrated that tools adhering to an open and flexible approach are valuable for facilitating communication and information sharing in design teams. Therefore, Helaba and Decision Cards are valuable for exploring what future tools for design documentation should offer, serving as a bridge between structured, rigid documentation and one which matches the free flow of ideas that characterizes the design process.

8.2.3 Learnings from Design Documentation

Karsenty (1996) and Burge (2008) evidenced the importance of evaluating the usefulness of design rationale notations in ongoing design processes. A decade later, it is still unclear how design rationale information can be captured by designers in ongoing processes, and how it can be used over time. Based on the explorations with designers, I found that designers use mostly basic tools to document their design processes, which implies that specialized tools are yet to be adopted. Thus, I argue that innovative solutions for capturing design rationale should be grounded on knowledge about design practices, and be evaluated over time. Therefore, it is relevant to understand how a documentation tool can actually help ongoing design processes

This challenge is addressed by ***RQ3 – what can we learn about documentation of ongoing UCD projects?*** To answer this question, Helaba and Decision Cards were used as tools to document a 15-week long student project that followed a UCD process, from initial idea generation to high-fidelity prototypes. This study produced rich data, which we analyzed in two distinct ways.

The first analysis involved a set of interviews and surveys to understand the *perceived usefulness of Helaba*. Secondly, a thematic analysis was conducted to provide an overview of the *information that is typically recorded* during the initial stages of UCD projects.

The results of these two distinctive analyses show that there is no single correct way to record design documentation, but lightweight tools can support the capture of design knowledge. This is reflected by the fact that participants were able to adapt Helaba to their own processes, rather than being limited to strict rules imposed by the system. Thus, this is a significant step towards offering tools that balance formal and creative approaches to document user-centered design processes.

The *visual communication components* of Helaba were useful to contextualize artefacts and create narratives around them throughout the different steps of the UCD process. The *shared workspace* was used to display a curated selection of artefacts, which represented milestones in the process. The combination between narratives and *curated artefacts* helped participants to build a cohesive story of their project over time. The content recorded in Helaba was used for (1) reflecting on previous agreements and ideas (e.g., retrospective thinking), and (2) finding new courses of action, especially in collaboration with others (e.g., prospective thinking).

Reflecting on the *purpose and level of detail* of the recorded content (see Sections 2.4.2 and 2.4.3 respectively), Helaba was useful as both a *reflective and communication tool*, and stimulated the creation of *formalized documentation*. Thus, I suggest that documentation tools should strive for workspaces that allow narratives to emerge together with artefacts, and a conversation space to generate new ideas in collaboration. These elements allow rationales to emerge organically, and in a potentially easier way than by creating an exhaustive documentation of the arguments for each design decision.

8.3 Implications of the Research Approach

The work in this PhD generated knowledge about the problems faced by designers when collaborating in multidisciplinary teams engaged in the UCD of interactive

systems. This knowledge was used to create tools looking for solutions to tackle these problems, and then through the application of these tools in relevant contexts, as means to yield knowledge about design practice. I used UCD as a philosophy to guide this work. Consequently, user centered design was both my *object of study*, as I studied teams engaging in user-centered design activities, and also as the *overarching approach* which guided my research work.

One interesting point of reflection are the implications of using UCD as an overarching approach on my design work. As examples, I discuss the design process of the first prototype of Helaba (Section 4.4) and the first version of the Decision Cards (Section 5.3). These examples highlight how problems and solutions co-evolved throughout my design process. This reflection presents further evidence of the progress of my ideas and the collaborative aspect of my work.

8.3.1 Reflecting on the Design Work

As mentioned in the Introduction chapter, the initial topic and framing for my research came from the EU FP7 project COnCEPT. This project situated me in the context of *creating digital tools to support collaborative design activities in the early stages of the design process*. However, as in every design process, I was faced with a wicked problem: what activities to support and how to start tackling them?

Guided by UCD principles, my first move was to organize interviews with target end-users, including a broad group of people involved in interaction design projects (see Section 2.3). What I found in this study was intriguing: while the early phases were seemingly chaotic and disorganized, designers seemed to *genuinely enjoy the process*. However, they yearned for tools that helped them to *organize the "boring" part of their work*, which appeared to be file management, remote communication, and documentation required to keep track of projects over time. My initial idea was to look for ways to "organize the chaos" to allow designers to do what they enjoy, but with a structure that permits them to get the boring tasks done in an easier way.

This initial idea of “organizing the chaos” resonated with writing in design engineering literature, which provided a starting point to inspire alternative solutions. In particular, I was inspired by the concept of *design rationale*, as a way for *capturing the why an artefact is the way it is*. These inspirations paved the way for the conceptual ideas of Helaba: a shared workspace to organize communication by including the “right” information about the rationale of artefacts. Figure 34 presents a few of the initial sketches and ideas of Helaba: asking and explaining “why” an artefact is a certain way, and integrating this with social interactions.

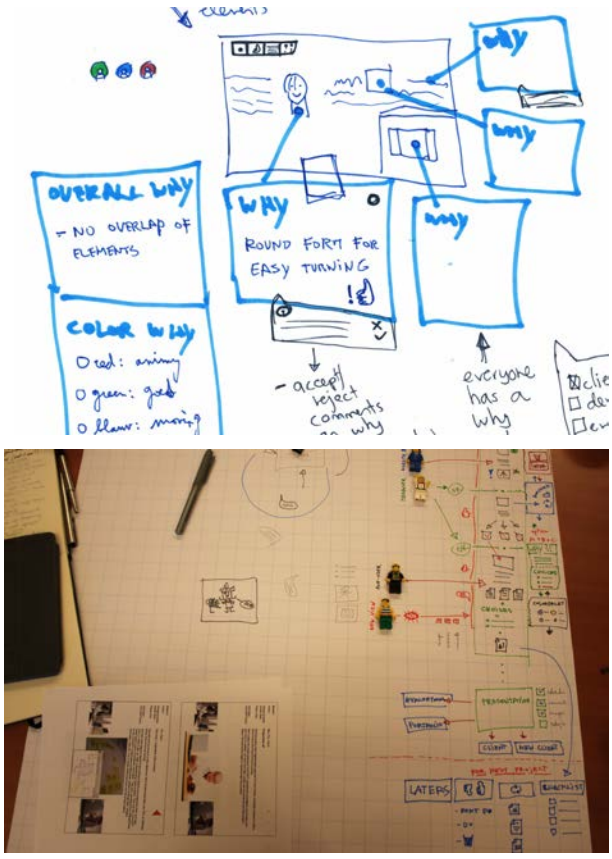

Figure 34. Early explorations that led to the creation of the first prototype of Helaba.

Initially, I envisioned that rationale information could be provided by loose interpretation of the QOC notation, which contains relevant *questions* about an

artefact, alternative *options* to answer the questions, and their *evaluation criteria* (MacLean et al., 1991). These ideas were iterated with both co-researchers of our research lab, and of the larger COnCEPT consortium, where several ideas were explored, iterated, and others discarded.

The initial concept of Helaba that emerged from these initial explorations was evolved into a prototype, shown in Figure 16 and described in Section 4.4. The paper version of this first prototype was evaluated with designers with the guidance of scenarios. These evaluations made evident that the concepts underpinning Helaba, which were mostly based on engineering design, would not be applicable to the way interaction designers work in the field. Having even a loose QOC notation to guide communication would be deterrent, since it would imply making discourses uniform, without consideration of personal or organizational preferences.

In retrospect, while working with design rationale notations was ultimately discarded, it *inspired me to balance approaches between what is proposed in engineering design literature to "organize the chaos," with more open and flexible approaches*. Thus, I kept the notion of design rationale to give a frame to what I wanted to explore: how designers document their work, and how we can facilitate it. More importantly, the first prototype of Helaba taught me that (1) artefact-based communication is a key aspect to support early design tasks, and (2) flexible workspaces to organize large amounts of information were worthwhile to be explored. These learnings are represented in the design directions in Section 2.5, which were later enriched with a *follow-up study focused on documentation practices of design researchers*, which was organized during the last year of my PhD to gather further evidence about documentation practices.

Working in a research project, I was able to conduct qualitative research in the field in parallel to the design work of Helaba. This allowed me to explore design practices in depth, which inspired further design directions. Being aware of the need of having a more contextualized understanding of design practices, I organized field observations of design meetings. The intention was learning how multidisciplinary communication happens "in action," and the role of artefacts to mediate these interactions (see Chapter 3). The main lessons learnt from these

observations were that *design rationale is recorded "in small pieces" and is contextualized with information of why a certain decision is taken and by whom*. Furthermore, these lessons served to inspire solutions that are placed "on top" of the process followed by designers, instead of looking for techniques for organizing communication as a whole. Literature supported this view and led me to think in terms of how certain artefacts, such as the prototypes and workflows used during meetings, could act as boundary objects to mediate meanings between different communities (Star, 2010).

Using the knowledge gathered in these engagements, I started to explore the initial concepts of Decision Cards, as shown in Figure 35 (left). This tool was conceived as space dedicated for decisions, where teams can focus on capturing information that is useful to guide the process, and that can help making others accountable for their contributions to the process.

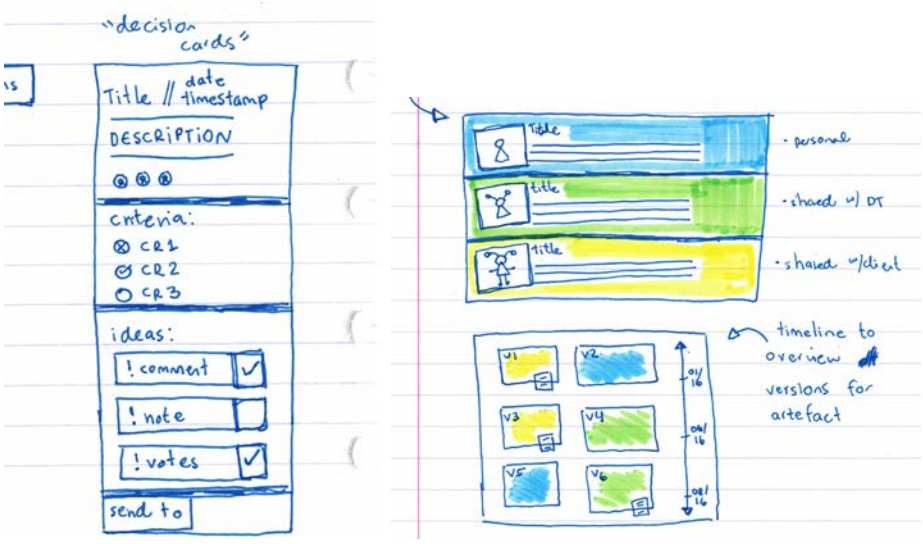

Figure 35. Early explorations that led to the creation of the first version of Decision Cards, and initial sketches on how to fit the Decision Cards into Helaba.

The Decision Cards were iterated first with co-researchers, when we explored how they could fit into the larger frame of Helaba. One of such explorations to interleave Helaba and Decision cards is illustrated in Figure 35 (right).

To assess their usefulness in context, the first version of the Decision Cards was used as a probe to investigate how they could be fitted into ongoing design activities (see Figure 23), for which I organized a workshop with novice designers. From this experience, reported in Chapter 5, I learnt that Decision Cards were suitable as tools to accompany and record – more than determine or guide – design decisions. Analyzing the way designers used the Decision Cards during this workshop made clear that: (1) less structure works best when it comes to design documentation, and (2) a low threshold format to convey ideas is an intuitive way to communicate rationale with other team members. As such, I bring forward Decision Cards are a "ready to use" tool that has the potential to be adapted to a variety of design activities, and is available for designers and researchers to use, explore, and extend.

It was clear that Decision Cards, while useful as standalone tools, were only a piece of the puzzle to document a broader design rationale. They needed to be contextualized with design artefacts in order to be valuable to have an overview of design processes, especially over time. I iterated the first version of the Decision Cards based on the feedback and insights gathered during the workshop with novice designers, refining aspects such as the terminology used and how they are attached to artefacts. The second version of the Decision Cards was integrated into Helaba, which enabled me to further assess them in controlled lab studies (Chapter 5) and in a longitudinal evaluation (Chapter 6 and 7).

While this reflection presents only a partial picture of the overall design process I followed, it serves to illustrate that tools evolved in a gradual and iterative way, together with my knowledge about design processes both at a practical and theoretical level. The ideas emerged in an explorative, emergent, and opportunistic way, guided by UCD as an underlying philosophy to keep the focus on users, conduct empirical evaluations, and design solutions iteratively.

8.3.2 Advantages and Limitations of the Research Approach

One of the core advantages of using UCD as an overarching approach was *applying a variety of techniques to engage with designers*. I used a variety of approaches, ranging from placing designers as *expert consultants* (e.g., during interviews), to *decision-makers* during participatory engagements (e.g., with workshops), where

designers had a say in the decision on how the tool should be iterated. Therefore, user-centered design provided a backbone for using different techniques to form a coherent research process, maintaining the focus on the target users. Using UCD as an approach to guide my research was dissimilar to UCD being applied to professional design practice (e.g., in industry settings), as *I sought to produce knowledge output, and tools that act as proof-of-concept more than finished products*. Furthermore, using UCD in the context of my research allowed me to conduct research and design work in parallel, which meant that I drew knowledge from both activities simultaneously.

However, the techniques used and the proposed tools are not without limitations. Qualitative user studies, such as those reported in Part I of this dissertation were particularly useful at the beginning of my research, as they served to *position myself within the research topic in a systematic way*, helping me to understand, experience, and interpret the activities of designers. In this sense, the research here presented produces a "rounded and contextual" understanding of the design practices, and brings forward recurrent situations, tools, people, in order to produce solutions that are grounded on empirical knowledge. Additionally, I framed this knowledge with existing literature in order to position my findings with "what is known" and reflect on how my findings lead to open new questions to explore. However, there are pitfalls on doing qualitative research. In particular, a criticism is that results can be seen as "'merely' anecdotal or at best illustrative" (Mason, 2002). To overcome this limitation, and as suggested by Mason (2002) and Flick (2009), I analyzed the data in a systematic and rigorous way, following sequential steps to gather, analyze, and report the patterns in the data. In particular, I used thematic analysis as a data analysis technique across all the studies, complemented by notions found in previous literature I found relevant at the moment of the analysis.

Another limitation of the user studies with designers is that they are targeted to designers and stakeholders working in the early stages of user-centered design processes. Thus, I avoid making generalizations to other design disciplines or the way all design professionals work. However, as the data analysis was rigorously conducted, I believe the findings can be useful for a wide variety of interaction design teams during the early stages, and in later stages of the process too. The

applicability of these principles to other domains could be investigated as future research.

The tools described (i.e., Helaba and Decision Cards) are explorative. While they are not finished products, they act as proof-of-concept realizations. Hence, these tools could be used to inform future solutions and frameworks, and they arguably have provided value in their current iteration. A potential limitation, as with any research or commercial tool, is that the adoption of these tools could be limited. However, I believe that what is important in this PhD, is the *knowledge these tools yielded from their conceptual development to the prototyping and assessment tasks*. Therefore, the concepts described here and the solutions proposed could be integrated into existing, more extensive tools, or serve as a guideline of what works for design documentation.

8.4 Future Directions

This section discusses future research directions that emerge from this PhD.

8.4.1 Extending the Findings to Different Settings

To ensure a balanced approach, the studies reported in this PhD involved a variety of people and projects related to user-centered design projects to create interactive systems, including designers with different levels of expertise (e.g., novice and experienced) working in different settings (e.g., industry, research, and educational). I identify two areas of interest for future work to extend the results reported in this dissertation: (1) apply the concepts to different design disciplines, and (2) deploy the proposed tools in different settings. Helaba could be deployed and assessed, for instance, in a design studio dedicated to graphical design to facilitate visual communication, in a small software company to enhance their user-centered techniques and approaches, or in a public environment to contain shared design artefacts and documents.

In professional settings, some designers or other team members may not be overly concerned with identifying the origin of ideas during the making process, focusing more on the design quality or meeting deadlines, or being innovative. However, I imagine that having digital tools that document particular instances of creativity, insights, or ideas, can serve to openly illustrate the value of their own

work, and that of other team members included in the project. In turn, I believe that identifying and keeping track of the origin of ideas has the potential to encourage individual and team confidence, and to show that design processes can be democratic. This might have the particular value in multidisciplinary teams by empowering all team members, and facilitating that they do not feel marginalized in design activities.

A public environment to deploy Helaba could be a Fablab or Makerspace. These are creative places where people could benefit from having a digital workspace such as ours for sharing annotated artefacts. For instance, Helaba can be used for people to build upon each other's designs, adding specifications about the artefacts they produce, or including instructions on how to engage with the materials and machinery available. Since Helaba does not impose a way of working, it could accommodate a variety of projects, and serve as an overview of artefacts that could be produced in the Makerspace. Much like the longitudinal evaluation reported in Part III, such deployments can help to understand how Helaba can support design projects in the long term, where the team composition and size are variable, or even as a "public" source of information about design artefacts.

The workshop with novice designers (Section 5.4.1) and the longitudinal evaluation of Helaba (Chapters 6 – 7) can be seen as initial investigations of the value of Helaba in educational contexts. We found that by analyzing their communication explicitly, we were able to expose the collaborative process of novice designers. An interesting future direction is to explore the usefulness of Helaba to train students on how to create design documentation. There are virtually no conventions on how to teach what to document for a design process, or how to do it (Edelson, 2002). An approach like Helaba can have advantages over traditional ways of teaching design documentation (e.g., journals or sketchbooks), as this tool activates knowledge (students communicate about design) and trains them to situate design as a team activity.

8.4.2 Expanding and Revisiting Design Directions

The tools proposed in this PhD (i.e., Helaba and Decision Cards) are based on the design directions that emerged from user studies with interaction design

practitioners, reported in Part I of this dissertation. Furthermore, they were evaluated iteratively with design practitioners. In this sense, the tools are embedded with existing practices of designers. However, these tools are only some of many possible solutions. Thus, future work could revisit these design directions to find alternative solutions, benefiting from the findings described in this body of work. For instance, it is interesting to let users import content from commonly-used tools (e.g., Dropbox and Skype) to Helaba. This could reduce the "double work" to record documentation and would allow designers to quickly create a curated information flow. It can be a more adequate solution than simply adding a chat or e-mail client into Helaba.

Additionally, I uncovered a design direction to explore how to include multidisciplinary points of view during design meetings (Chapter 3). I identified that a balanced inclusion of a variety of points of view and contributions can promote accountability and shared ownership. To achieve this benefit, people from different disciplines need to recognize their input and link their ideas to design artefacts in a visible way. This design direction was not directly explored in this PhD, and as such, is interesting for future research. A potential starting point for this exploration are the digital tools for equal participation that have been investigated in previous research.

The PICTIVE technique (Muller, 1991), for instance, provides a visual space for users and developers to contribute in prototyping activities equally, while their interactions are video-recorded. Second Messenger is a tool that uses speech recognition to provide a "social information display" to visualize the contributions of team members, which was found to withhold over-participation (DiMicco & Bender, 2004; Norton, DiMicco, Caneel, & Ariely, 2004). The strengths of the aforementioned tools is that they promote equal participation, and they are useful to document the design process by capturing the interactions that happen naturally between the team.

Future explorations could include a systematic analysis of similar technologies in order to compare and contrast different approaches to design documentation (e.g., engineering and creative approaches). Such analysis could establish a

baseline on what approaches are more efficient and effective in both short and long term to create design documentation.

8.4.3 Generating Large Archives of Design Insights

Previous research (Sharmin et al., 2009) and our findings indicate that one core issue for design practitioners is organizing the large amount of information that is generated in processes. We tackled this issue with the Learn Repository of Helaba. This feature probed to be a good starting point to structure and overview design processes over time. However, it remains a limitation that the content needs to be added manually (e.g., users need to upload each image), and that its scalability could be compromised for long-term design projects (e.g., visualize and retrieve artefacts created over the course of a few years). Future research could explore how workspaces like Helaba can be used as an archive to organize artefacts in an automatic way, facilitating to intuitively visualize, sort, and access the content.

On a practical level, such archive should allow designers to add various media sources, such as videos, photos, sketches. Adding this media to the archive should be facilitated by using technologies which are already used by designers (e.g., connected to their smartphone camera and Dropbox), and organize the information in an automated way using metadata such as date, version, and contributors. This metadata could be extracted automatically, for instance, from the Decision Cards attached to artefacts. On a conceptual level, this archive could be used as a source of knowledge with design artefacts insights. This archive could be for personal use, shared locally in a design studio, or even used to build a space available across the design community where people feel empowered to share their ideas and find sources of inspiration. Key issues to consider for such community would be privacy, intellectual property, and a way to search into the rationale of the different elements.

8.5 Closing Remarks

In the scope of this thesis, I conducted in-depth user studies *to delineate the practices, tools, and artefacts used by design teams working in user-centered design of interactive systems*. The user studies uncovered bottlenecks situated in multidisciplinary communication, information sharing, and documentation of the

design process and its outcomes. These issues highlighted the need for appropriate tools to create design documentation in a way that respects the work practices of designers. Accordingly, this work has contributed to *two tools for documenting design rationale. These tools provide a shared workspace where interactions revolve around design artefacts, conversations, and decisions*. The strength of these tools is to create design documentation in a way that is integrated into existing work practices of designers. The findings from empirically evaluating these tools demonstrated that a *lightweight approach to design documentation supports designers in keeping track of their decisions over time*. Additionally, the externalized information helped teams to reflect on their work, and provided a space to collaboratively generate new ideas.

Appendices

This section contains different documents that were used during our user studies and explorations.

A.1 Interviews with Professional Designers

This section lists the semi-structured interview questions used for the user study with professional designers, as described in Section 2.3.1.

Interview Protocol

Please recall a memorable or challenging project, and tell me about your activities on that project:

1. Who was involved?
    a. What was their role?
    b. How did you collaborate with your team?
    c. How frequently did you communicate with your team? (formal and informal)
    d. What communication tools were used?
2. What other tools did you use?
    a. Which of these tools were used to collaborate?
    b. Which one is your favorite tool for this kind of setting? (please detail features)
3. Did you create any artefacts or documents?
    a. Were they created individually or collaboratively?
    b. How were they disseminated across the team? (how, with who)
    c. What tools were used to create these artefacts?
    d. Do artefacts have a standardized format?
    e. How do you track their changes and control versions?
    f. How do you store and organize artefacts?

A.2 Interviews with Design Researchers

This section lists the semi-structured interview questions used for the user study with professional designers, as described in Section 2.4.1.

Interview Protocol

1. What do you understand with "documentation" of a design process? (What sort of information is in there, how else you call it, what forms it have, how it can be shared)
2. Do you document your design processes?
    a. If yes, what do you document? (what ideas/artefacts do you choose to store, physical vs. digital archives)
    b. If not, why not?
3. How do you create this documentation? (tactics for storing ideas & decisions)
    a. What tools do you use?
    b. How do you link ideas/knowledge and artefacts? (rationale)
4. How do you use this documentation?
    a. How often do you access it?
    b. How does it influence your work?
    c. How does this documentation support your professional and/or organizational development?
5. Do you share/disseminate this documentation to others?
    a. If yes, to who and how?
    b. Do you think the documentation helps you to persuade others about your design process or its outcomes?
    c. If no, why not?

A.3 Co-Located Workshop with Novice Designers

This section lists the two design briefs used for the co-located workshop with novice designers and Decision Cards, as described in Section 5.4.1.

Design Brief 1

You created a prototype to support remote collaboration for the [academic course name]. What features make your prototype unique? In this session, your source of inspiration are the unique, one-of-a-kind, and even contradictory features between the different prototypes. Ideate for unexpected types of users, in unexpected situations, using these unique features.

This assignment

- Generate as many ideas as possible about the unique features of the prototypes. Break the paradigm, and consider non-conventional ideas and solutions focusing on both positive and negative aspects.
- Assume that everything is possible, think about the "perfect future" with no technological constrains.
- Express your solutions and ideas by means of sketches, complete with textual description and annotations.
- Use Decision Cards to keep track of your group discussion.
- Create 2 personas that are unlikely users of your current prototypes. Use the personas you created for this project as inspiration, but now turn to the opposite (e.g., a design practitioner who is about to retire, has never been familiar with technology, and don't see the value in remote collaboration).

Design Brief 2

This assignment

- Present the concepts from the design brief #1 to the members of the other team, reflecting on the techniques you used and the challenges you faced during the discussion. Explain the ideas and rationale behind your decisions.
- Evaluate the concepts and select the most non-conventional solutions and ideas.

- Express the selected solutions and ideas by means of sketches, complete with textual description and annotations.
- Document your solutions using Decision Cards.
- Prepare a presentation about your ideas for the facilitators of this session. In your presentation, include:

    a. Principal solution(s) with a short scenario;
    b. A description of the ideas behind the solution(s) (personas, sketches, inspiration, ideas); and
    c. Assume that facilitators don't know anything about your project: give a full overview of the process followed and defend the decision taken.

A.4 Remote Workshop with Expert Designers

This section lists the scenarios used for the remote workshop with expert designers and Decision Cards, as described in Section 5.4.1.

Scenario A

Getting on board with CreativesCO

Today it's your first day working with CreativesCO, a small design studio specialized in creating interactive systems. You're very excited with this new opportunity and want to do your very best. Rick Moore, the project manager, tells you that your first assignment is to get up-to-date with the EcoHOME project. To get things started, Rick explains you that CreativesCO collaborate remotely using Helaba. Rick provides you the login details for accessing Helaba, and asks you to enter to the system to get familiarized with the EcoHOME project. Please work on the task list below.

- Task 1: Sign in to Helaba using the [username] and [password].
- Task 2: Open the EcoHOME project. Find out who is involved in this project and what is it about.
- Task 3: Open the Eco-shower task of the EcoHOME project.
- Task 4: Open the second version of the storyboard for the Eco-shower task.
- Task 5: Briefly explore the Notes, Evaluation, and Decision Cards created in this version of the storyboard.

Scenario B

You start working in the Eco-shower task for the EcoHOME project. Your job is to create a new version of the mockup for the Eco-shower app. Rick Moore, the project manager, asks you to use the previous artefacts for the Eco-shower task to inform your sketches. Please work on the task list below.

- Task 1: Open the Eco-shower task. Find out what is this task about.
- Task 2: Explore the previous artefacts for the Eco-shower task to inform your ideas.
- Task3: Generate initial sketches for the Eco-shower app mockup based on the previous decisions.

Scenario C

After finalizing your sketch, you would like to ask for feedback and questions to the project manager and client for the EcoHOME project. It is not possible to do this face-to-face at this moment because your colleagues are not in the office, but you can document your ideas and questions using Helaba. It is important that you explain the rationale behind your sketch, augmenting on why you made certain design choices. Please work on the task list below.

- Task 1: Upload your sketch to the Mockup artefact of the Eco-shower task.
- Task 2: Add at least 3 Notes to clarify the elements of your sketch.
- Task 3: Using the Notes you just created, start two conversations with your team to ask the questions you find relevant.
- Task 4: Create at least 2 Evaluation topics according to what feedback you expect to ask your team.

Scenario D

While you were having a short break, some members of your team logged into Helaba and gave you feedback on your sketch. You are looking forward to find out their opinions and answers to your questions. With the information that they share you, you will be able to make decisions regarding the mockup for the Eco-shower app. Please work on the task list below.

- Task 1: Review the conversations you created. Add a follow-up question or comment to each conversation.
- Task 2: Review the feedback you received to the Evaluation topics you created.
- Task 3: Create at least 2 Decision Cards based on the results of the input you received from your team.

A.5 Features for Traceability in Commercial Tools

	Shared workspace				Artefact-based communication		Awareness of artefact evolution		
	Shared workspace	*Connected with external tools*	*Track recent activities of the team*	*Team and task management*	*Annotations in artefact*	*Synchronous / asynchronous communication*	*File structure*	*Version control/ management*	*Record decisions explicitly*
ConceptShare	✓	X	✓	✓	✓	✓	✓	✓	X
Notable	X	X	✓	X	✓	✓	Not clear	X	X
Firefly	X	X	X	✓	✓	✓	✓	✓	X
Skwibl	✓	✓	✓	✓	✓	✓	✓	✓	X
Designdrop	X	X	Not clear	X	✓	✓	X	✓	X
Govisually	✓	✓	✓	✓	✓	✓	✓	✓	✓
Concept inbox	✓	✓	✓	✓	✓	✓	✓	✓	X
Redpen	✓	✓	✓	X	✓	✓	✓	✓	X
Realtime board	✓	✓	✓	✓	✓	✓	✓	✓	X
InVision	✓	✓	✓	✓	✓	✓	✓	✓	X
Wake	✓	✓	✓	✓	✓	✓	✓	✓	X
Conceptboard	✓	✓	✓	✓	✓	✓	✓	✓	X
Prevue	✓	X	Not clear	Not clear	✓	✓	✓	Not clear	X
Apollo	X	X	X	X	✓	✓	X	✓	X
Redmark	X	X	X	X	✓	✓	X	✓	X
Bounce	X	X	X	X	✓	✓	X	X	X

The URLs mentioned below refer to the commercial tools listed in the previous table.

https://www.conceptshare.com

http://notableapp.com

https://www.fireflyapp.com

http://skwibl.com

https://www.designdrop.io

http://www.govisually.com

http://conceptinbox.com

https://redpen.io

https://realtimeboard.com

https://www.invisionapp.com

https://wake.com

https://conceptboard.com

https://prevue.it

http://www.useapollo.com

http://redmark.com

http://www.bounceapp.com

A.6 Online Survey about Experiences with Helaba

This section presents the online survey used for the longitudinal evaluation of Helaba during the *task analysis phase* of the UCD project. Identical surveys were used for the different stages of the UCD process. This experiment is described in Section 6.4.

Online Survey (Task analysis phase)

Please answer the following questions about your experiences using Helaba during the "task analysis" phase of the UCD process. Your responses will be treated as anonymous and confidential.

(* Required)

Please enter your group number *

_____

Can you describe how you used Helaba during the "task analysis" phase? *

_____

Artefacts and versions

How many of the artefacts you created for the “task analysis” phase were recorded in Helaba? *

- ☐ All artefacts
- ☐ Almost all artefacts
- ☐ Some artefacts
- ☐ Almost none of the artefacts
- ☐ None of the artefacts

How many versions of these artefacts did you upload to Helaba? *

- ☐ All versions
- ☐ Almost all versions
- ☐ Some versions
- ☐ Almost none of the versions
- ☐ None of the versions

How did you select what artefacts and versions to upload into Helaba? *

_____

Team discussions

How much of your team discussions for the "task analysis" phase were recorded in Helaba? *

- ☐ All discussions
- ☐ Almost all discussions
- ☐ Some discussions
- ☐ Almost none of the discussions
- ☐ None of the discussions

How did you select what team discussions to record into Helaba? *

_____

Decisions

How much of your decisions for the "task analysis" phase were recorded in Helaba? (i.e., Decision Cards) *

- ☐ All decisions

- □ Almost all decisions
- □ Some decisions
- □ Almost none of the decisions
- □ None of the decisions

How did you select what decisions to record into Helaba? *

_____

General questions

Besides Helaba, what other tools you used to communicate and document your work during this phase? (Slack, Skype, MS Word, Google Drive, or other tools) *

_____

Do you have any technical issue or suggestion about Helaba to report?

_____

Nederlandstalige Samenvatting

In dit doctoraat onderzoek ik de manier waarop ontwerpteams samenwerken wanneer ze interactieve systemen realiseren volgens een gebruikersgericht ontwerpproces, en de ondersteunende tools die ze daarbij aanwenden. Hierbij leg ik de nadruk op de werkwijze waarmee ontwerpers hun “design rationale” documenteren, en hoe ze hierover communiceren met teamleden die een andere discipline als achtergrond hebben. Eerder onderzoek heeft aangetoond dat creativiteit en innovatie gestimuleerd worden door het betrekken van diverse actoren bij, en het voeren van uiteenlopende debatten in design activiteiten. Nochtans ontstaan misverstanden in een team vaak door de verscheidenheid van prioriteiten, terminologie en voorkeuren bij de teamleden. Bijgevolg zijn ontwerpers zoekende naar goede manieren om te communiceren over de design rationale, met inbegrip van de voorgestelde ontwerpoplossing en waarom deze geschikt is in een gegeven context.

Hoewel reeds diverse tools voorgesteld werden om design rationale te documenteren, bereiken ze zelden de status van een tool die breed ingang gevonden heeft in professionele middens, onder andere omdat ze leiden tot beperkingen en overmatige structurering van het denkproces tijdens design activiteiten. Mijn onderzoek probeert een antwoord voor deze uitdagingen te bieden door de manier te bestuderen waarop ontwerpers samenwerken. Voortbouwend op dat inzicht stel ik tools voor om de design rationale te documenteren, op basis van – tussentijdse - design resultaten, en passend bij hedendaagse ontwerppraktijken. Daarom stel ik in mijn doctoraat de volgende drie kernbijdragen als onderzoeksresultaten voor.

Vooreerst leg ik de problemen bloot die ontwerpers ondervinden bij het samenwerken, en deze zijn o.a. multidisciplinaire communicatie, delen van informatie, en het documenteren van zowel het ontwerpproces als de ontwerpresultaten. Zo kom ik tot een aantal mogelijke pistes voor de realisatie van tools ter ondersteuning van de samenwerking in het design team, waarbij de gangbare processen en aanpakken gerespecteerd worden.

De twee voorgestelde tools om op toegankelijke wijze design rationale en ontwerpbeslissingen te documenteren vormen een tweede resultaat van mijn doctoraat. Deze tools activeren communicatie in het team en creativiteit door een gedeelde werkruimte te voorzien voor vlotte visuele communicatie op basis van artefacten of tussentijdse ontwerpresultaten.

Tenslotte toon ik in dit doctoraatsonderzoek aan dat onze benadering van design documentatie toelaat dat de design rationale op organische wijze evolueert samen met tussentijdse design resultaten (artefacten), en dat ze ontwerpteams aanspoort tot collaboratieve ideeëngeneratie. Onze tools helpen ontwerpteams te reflecteren over verwezenlijkte resultaten en na te denken over toekomstpaden die het bewustzijn over designpraktijken aanscherpen. Zo helpen de tools bij het opvolgen van design rationale en design beslissingen doorheen de projectuitvoering.

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