Catching Trains of Thought

UX Guidelines for Facilitating Knowledge Exchange Between Makers

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Master of Arts thesis abstract

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Abstract
This thesis establishes directions for the design of the user experience of a service that could facilitate knowledge exchange practices amongst makers. To achieve this the thesis sets out to answer the question “How to design the user experience of a multi-platform application to enable it to facilitate knowledge exchange between makers?”. A process consisting of a research for design and a research through design stage is utilized to generate a suitable answer.

The research for design stage includes a literature review and field research. The literature review investigates the motivations for developing as a maker, the physical spaces in which makers are active, communities of practice, and knowledge creation in collaborative processes. The key findings from this review are validated and furthered upon through field research. The field research explores activity in and on maker communities in Helsinki through interviews and collaborative design sessions with local makers. The findings from the research for design stage are then condensed into twelve design directions.

The research through design stage describes the design, evaluation and testing of two interactive prototypes of a multi-platform application. The first prototype is used as a presentation aid during evaluations on two events, a large Maker Faire and the Spring Demo Day in Aalto University Media Lab. Based on the evaluations the prototype is iterated and then subjected to usability tests in a Fab Lab. The results of the research through design stage reveal three themes regarding the user experience of a system aimed to facilitate knowledge exchange.

To answer the main question the design directions and the themes are combined. The findings urge designers of systems aiming to facilitate knowledge exchange between makers to pay attention to three guidelines. These guidelines are: stories of creativity, the overlap of intuition and education, and the need for structure and support.

The findings of this project provide insights necessary to reduce the loss of knowledge in maker communities, and in this way develop their efficacy. Improving the ability of these communities is argued to have a positive influence on existing industrial processes.

The author collaborates with Taro Morimoto during the project described in this thesis. Taro Morimoto utilized this project to research the digital ecosystem of makers and the technical aspects of the multi-platform application as part of his thesis for the Master of Arts in New Media.

Keywords  Makers, Tacit knowledge, Knowledge exchange, User experience, Co-design, Prototyping, Human-computer interaction, Mobile, Collaboration
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Next, I would like to express my reverence for the flexibility and enthusiasm of Timo Nyberg. The interest, feedback and support we received during the project from him and the Social Manufacturing FiDiPro Project was as unexpected as it was indispensible.

I do not know how to thank the maker communities of Helsinki enough. The whole process described in this thesis would have been impossible without the willingness of the Hacklab Helsinki, Kaupunkiverstas, Aalto Fablab, Made in Kallio, Maker Faire UK, and numerous individuals to participate in this project. The same is true for the people that have been interviewed and others that have given their time and attention to this undertaking. For all of you who participated I hope the results of this thesis will be build upon and developed to support you in your future activities.

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PART I: STUDY

1. INTRODUCTION
**MOTIVATION**

Expert amateurs?
This thesis is the culmination of my efforts within the MA Collaborative and Industrial Design program at the Aalto University’s department of Arts, Architecture and Design. I have chosen to focus these efforts on design for the so-called maker movement. Standing at the beginning of my career as a designer it seems impossible to ignore the influence of this movement’s emergent collaborative practices on the field of design. But exploring these practices is not just way of preparing myself for the future; I relate to this movement because I also enjoy making things. During this project I applied a collaborative design approach to generate directions for the design of a multi-platform application. This process of research and design involved: literature review, interviews, co-design sessions, interactive prototypes, and usability testing.

Collaborative thesis
During the past two years Aalto University I have been offered opportunities for crossing boundaries and interdisciplinary collaboration beyond my wildest dreams. After being able to take courses in five different schools and piecing together an intellectual foundation across disciplines, I found that the merits of working together with people with different backgrounds and expertise represent the core values of the university as I know it. To honor these invaluable lessons I chose to collaborate with another student during this thesis project. I hope the results of this thesis can inspire future students to do the same.

The collaboration started after Taro Morimoto, student in the MA New Media in the department of Media, and me realized that our thesis projects were somewhat compatible. We decided to sit down and investigate the overlap between our topics. I was initially aiming for a project involving user research and designing a concept for a digital service and he was planning to implement and build such a service. Our concepts both revolved around facilitating collaborative creativity. It didn’t take long to recognize the mutual benefit we could derive from working together. In retrospect I’m happy to say that we were able to synthesize our efforts. If we hadn’t shared this project neither of us would have been able to conduct the research process and iterate the design as we did. We were able to utilize design tools and functional prototypes in ways that wouldn’t have been possible without collaboration. In addition, although our project is one and the same, our theses have remained clearly distinct from each other. For a more detailed description of the structures of the theses, please refer to 1.4.

**BACKGROUND**

Finding an opportunity for UX design
I am interested in the idea of involving the end user in the process of design. I strongly believe that in order to create lasting solutions a designer needs to understand what the end user values. To reach that understanding it is necessary to involve the end user in the creative process of design. The maker movement caught my attention because they expand on this line of thought by completely appropriating the design process.
The maker movement consists of a huge variety of amateurs independently creating DIY solutions for their problems (Anderson 2012). Typical for this movement is the dependence on the Internet as means of communication. With this movement being relatively new and in the process of inventing itself an opportunity arose to create something meaningful.

**Learning communities**

Kuznetsov and Paulos’s study amongst 2600 members of online DIY communities indicates that information exchange is a core value of those communities. Although DIY projects are predominantly solitary processes, the researchers find they are often complemented by activity in a community. More than 90 percent of the respondents share a part of their projects online (Figure 1). It was found that participants were often involved in more than one DIY community. This was done to exchange information with people from different technical, artistic and professional backgrounds.

According to the research the sharing does not obstruct activity of the participants, it is accessible for individuals from nearly any background and does not rely on exceptional skills or equipment. Respondents share their projects and knowledge largely through pictures and written questions and comments (Figure 2). They value video and step-by-step instructions over other contribution formats, yet these appear the least common of contributions (Kuznetsov and Paulos 2010).

Figure 3 shows that nearly 80 percent of the respondents sought out opportunities to connect to like-minded people (Kuznetsov and Paulos 2010). In their research on How-to sharing Torrey, McDonald, Shilit and Bly find that shared content functions as a user profile within an expertise location system (Torrey et al. 2007). Kuznetsov et al support the idea that DIY communities serve as instruments of learning and find that learning is the second ranking motivation for contributing to DIY communities and projects. Their respondents point out that exchanging information facilitates their learning. This leads Kuznetsov et al into the conclusion that “DIY is a culture that aspires to explore, experiment and understand” (Kuznetsov and Paulos 2010). Philips et al recognize similarities between sharing as a way to explore one’s own understanding and “learning by teaching” methods (Phillips et al. 2013).

**Doing it for fun**

The DIY communities are aware of their role in educational processes and intend to strengthen that role. Several key communities have decreed that information on projects should be open and accessible in order for others to learn from (Jalopy, Torrone, and Hill 2006; “The Fab Charter” 2015). The altruistic drive to help others and society at large has been ascribed to DIY contributors by multiple studies (Torrey et al. 2007; Kuznetsov and Paulos 2010; P. Wolf et al. 2015). However, these also emphasize that, despite the prevalence of this argument, it mostly plays an inferior role compared to more hedonistic motivational drivers such as personal satisfaction and fun.

Research indicates that satisfaction is received from the making itself (P. Wolf et al. 2015) and when other people appropriated a shared project (Torrey et al. 2007). Fun is experienced when others recognize shared projects as creative (P. Wolf et al. 2015). As is visible in Figure 3 and Figure 4 expressing creativity and gathering inspiration in order to get creative ideas are the main motivators for contributing to the community. If work is perceived as not creative, i.e. uninteresting, not novel or too simple, the contributor will not share it (Figure 5). Therefor “fun” can be understood as “being able to be creative”.

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1. INTRODUCTION
Figure 1. DIY projects shared with DIY communities. More than 90 percent of all the respondents shared projects. Projects with a longer duration had a higher chance of being shared (Kuznetsov and Paulos 2010).

Figure 2. Contributions to DIY communities by frequency. These findings indicate a culture where a lively sharing of questions, comments and answers is predominant (Kuznetsov and Paulos 2010).
Figure 3. Motivations for contributing to DIY communities (Kuznetsov and Paulos 2010).

- Get inspiration and new ideas for future projects
- Learn new concepts
- Meet new people who share similar interests as me
- Receive feedback about my own projects
- Educate others, share information
- Showcase my ideas and skills
- Document or archive my work
- Give back to the community
- Improve my reputation and/or website traffic
- Find employment opportunities
- Express myself, be creative
- Learn new skills
- Create things I can not buy
- Personalize my things
- Solve problems, challenge myself
- Recycle or refurbish materials
- Showcase my skills
- Save money
- Work and spend time with my friends
- Impress other people
- Make money
- Gain internet fame or online reputation

Figure 4. Motivations for contributing to DIY projects (Kuznetsov and Paulos 2010).

- I don't have enough time
- My projects are too easy or simple
- My projects are not novel or creative
- My projects are not interesting
- I don't have equipment to document my work
- I don't want people to 'steal' my ideas
- I prefer to share through other mediums
- I don't have skills to edit and share my work
- I don't want my work to be critiqued
- My projects are too advanced or complex

Figure 5. Deterrents for sharing DIY work with DIY communities (Kuznetsov and Paulos 2010).
Since DIY practices have been recognized as ways to express individuality (Rosner and Bean 2009) and shared content as reflecting individual makers (Torrey et al. 2007; McKay et al. 2015) both “fun” and “satisfaction” are also related to the establishing of one’s individuality.

**Problem: Documentation is not fun**

Although the information exchange on online media is bigger than ever before, and online DIY communities are thriving, research in the physical DIY spaces called Fab Labs reveals a lacking ability to persuade members to document and share their projects (Troxler and Zijp 2013; P. Wolf et al. 2015; Eychenne 2012). This is highly problematic for Fab Labs, as “contributing to documentation and instruction” is included in their top three of most important responsibilities in their manifesto “The Fab Charter” (“The Fab Charter” 2015). Dismissing motivational barriers related to legal issues and willingness to share, Wolf, Troxler, Kocher, Harboe and Gaudenz (P. Wolf et al. 2015) indicate that the root of the problem lies with documentation. They state “Sharing newly created commons back globally and accessible to everybody (...) implies the use of online communication means and therefore previous documentation as conditio sine qua non.” before demonstrating that the task of documenting is being perceived as tedious and not being fun (P. Wolf et al. 2015).

Wolf et al. also point out that documentation is hindered further because of the characteristics of the information that is supposed to be shared (P. Wolf et al. 2015). Although not directly addressing the potential problems they might cause, Kuznetsov et al. recognized these characteristics as well. They distinguish between communities revolving around the creation of digital artifacts (software, articles or blogs) and physical artifacts (DIY). Based on their findings they hypothesize that DIY communities exchange “meta information”: personal experiences and knowledge from creating physical objects (Kuznetsov and Paulos 2010). Polanyi specified this particular type of knowledge as “Tacit Knowledge” (Polanyi 1966).

Although doubting its efficacy of managing bodies of knowledge, Wolf et al. hypothesize that easy to use and “fun” technology, which will allow users to build upon their pride, might be a possible solution (P. Wolf et al. 2015). It is here where I identified the opportunity for UX design to become involved.

**KEY FINDINGS**

- **DIY contributors are involved in multiple communities to locate and exchange a variety of information and expertise.**
- **DIY is a culture that aspires to explore, experiment and understand.**
- **Contributing to DIY communities is done to establish one’s individuality.**
- **Positive feedback on creativity is a main driver for DIY contributors.**
- **Users of physical DIY spaces perceive the activity of documentation as tedious and not fun.**
- **Documenting a DIY project is difficult because the creation of physical artifacts involves tacit knowledge.**
- **UX design can help to create meaningful solutions for the problems with documenting DIY projects.**
FRAMING THE PROJECT

This thesis builds on the assumption that “UX design can help to create meaningful solutions for the problems linked with documenting DIY projects”. First a literature review will be conducted in order to provide a theoretical understanding of the situation and to contextualize the design. To validate the findings of the review and to articulate design directions the project utilizes field research involving interviews and co-design sessions. After this the project will then continue to develop the frame of understanding through the design, evaluation, and testing of two prototypes. The combined findings of the project will be delivered as a series of recommendations for designing the user experience (UX) of a multi-platform application able to facilitate knowledge exchange between makers.

The scope of the literature review in this thesis is set to gain a thorough understanding the identity formation process of makers. The review investigates relevant collaborative knowledge exchange activity and points out challenges for the design of infrastructure supporting such collaboration. There will not be extensive inquiry into the economic or political impacts of the maker movement, neither will there be any benchmarking of existing services or technology that could facilitate the processes that are researched. These are subjects that are researched in the thesis of Taro Morimoto, which informed the technical design of the prototypes.

During the project the field research and construction of the prototypes have been done collaboratively, with each of us taking the lead in activities related to our own field of expertise. For instance during the construction of the prototypes I carried the responsibility for the design of the interface elements while Taro was in control of the technical architecture. All the individual effort is recorded in our own theses and documentation of collaborative activity found its place in the appendices A until E. In the theses we identify key findings and directions for our individual activities based on these appendices. In this thesis the key findings will be analysed and condensed in design directions and UX themes.
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Figure 6. The structure of both theses next to each other
THESIS STRUCTURE

As can be seen in Figure 6 the two theses have separate structures with the only overlap in content being the shared documentation of research activities and prototypes. The structures show great similarity, with the most notable difference being that this thesis has been divided into four parts, which describe:

1. The study
2. The research for design
3. The research through design
4. The results

It is recommended to browse through the appendices at the stage they are mentioned in Figure 6. The appendices can be downloaded at [http://bit.ly/1LCt6tB](http://bit.ly/1LCt6tB) or [https://dl.dropboxusercontent.com/u/11851471/Appendices%20MA%20Thesis%20Koert%20Jobse.pdf](https://dl.dropboxusercontent.com/u/11851471/Appendices%20MA%20Thesis%20Koert%20Jobse.pdf).

For the people that are interested the source code of the prototypes is available online. You can find the first prototype at [https://github.com/taromorimoto/pelori/releases/tag/MakerFaireUK](https://github.com/taromorimoto/pelori/releases/tag/MakerFaireUK) and the second prototype at [https://github.com/taromorimoto/pelori](https://github.com/taromorimoto/pelori)

RESEARCH QUESTION

This thesis aims to investigate design solutions for problems related to knowledge exchange activities between makers. Since it was identified that these activities benefit greatly from communication technology, the thesis project chooses to explore the design of a multi-platform application. This thesis limits itself to formulating directions for the design of the user experience (UX) of such a system.

The main question is as follows:

“How to design the UX of a multi-platform application to enable it to facilitate knowledge exchange between makers?”

The author is aware that UX can be understood in a variety of ways, and that there are several definitions present in the field (Roto et al. 2015). However, this thesis is not aimed to develop these ways of understanding UX and chooses to utilize a common understanding of UX. The definition found in the international standard on ergonomics of human system interaction, ISO 9241-210.2010 (British Standards Institution and International Organization for Standardization 2010), is regarded as acceptable in this context. So user experience or UX refers in this thesis to “a person’s perceptions and responses that result from the use or anticipated use of a product, system or service”.

Other terms mentioned in this question will be elaborated in the literature review.
2. METHODOLOGY
PROJECT STRUCTURE
RESEARCH METHODS
PROJECT STRUCTURE

This thesis is part of a research-oriented design process (Fallman 2009) that is aimed to provide a functional service system for collaboration between makers. This larger project is not a subject in this thesis. The main target of this thesis is answering the main question. The subject of this thesis is thus a design-oriented research process (Fallman 2009; Fallman 2003). According to Fallman a design-oriented research project is “a conduct which seeks to produce new knowledge by involving design activities in the research process. Here, design is used to drive and propel research.” (Fallman 2009). The designed products, i.e. the prototypes, involved in this project are thus not to be perceived as the final goal, but rather as a means to provide the answer to the main question.

Design-oriented research is also referred to as ‘Research through Design’ by Frayling (Frayling and Royal College of Art 1993). Frayling distinguishes between ‘Research for Design’, ‘Research through Design’, and ‘Research about Design’, and Frankel and Racine (Frankel and Racine 2010) elaborate on this. According to them research for design is the closest to the common understanding of ‘Design Research’, which involves user-centered studies, such as ethnographic methods and usability testing to inform a design. Research about design researches design as an activity, as in design history and design theory (Frankel and Racine 2010).

Golsteijn, Van den Hoven, Frohlich and Sellen (Golsteijn, Hoven, et al. 2014) show that research for design and research through design can successfully be applied in an iterative project aimed to create generate knowledge. To be able to answer the main question, this thesis project initially starts as research for design (described in Part 2) and proceeds to research through design in the later stages (described in Part 3).

Outside of the literature review the research is structured loosely like, at least according to Spinuzzi, is common for a Participatory Design project (Spinuzzi 2005). The participatory design approach he describes fits this project. It allows exploration of the tacit knowledge exchange in maker communities. This pragmatic approach can be considered an excellent way to validate and contextualize the findings from the literature review. The activities during this project can be organized according to Spinuzzi’s three stages in the following way:

1. Initial exploration of work
   - Interviews with experts
   - Observations during site visits
2. Discovery processes
   - Co-design sessions with local Makers
3. Prototyping
   - Prototype evaluation on a Maker Faire
   - Prototype testing with makers
Spinuzzi points out that participatory design researchers often apply the ethnographical research during the first stage in a loose fashion (Spinuzzi 2005); and in this we are by no means an exception. He warns that results of these loosely applied methods can cause the illusion that the research provides increased understanding while in fact does not.

To remedy these delusions there is a need for repeated reflexivity and agreement with the users (Spinuzzi 2005). This project reflects on the findings by triangulating the results with the findings of the literature review, and finds agreement with users by evaluating a prototype into which our assumptions are expressed. Based on this the prototype is iterated and again brought back to the users for testing. To increase the quality of the evaluations (Cardenas-Claros and Gruba 2010) the prototypes are functional and developed as they were part of an agile software development project (“What Is Agile?” 2015) (Larman 2004).

Even though this project carries the characteristics of a participatory design study, I prefer to not refer to it at such. A participatory design project needs a much more extensive involvement of the participants in the design process than the involvement in this project. Instead this project can be called a collaborative design or co-design project, in which the participants inform the design during various stages.

Since this project revolves around the creation of a platform for collaboration, it is important to acknowledge limitations of this research process. Design can only provide the infrastructure for a community, but the community itself can only emerge on that structure and cannot be designed (Löwgren 2015). To get a deep understanding on how these social structures develop the application has to be launched and used in real-use situations. This is something we were unable to do during this thesis project.

Figure 7 visualizes the thesis structures accompanied by the aforementioned design approaches.
RESEARCH METHODS

Expert Interviews
Taro Morimoto and me conducted 14 expert interviews together and on location. These interviews were not recorded and transcribed, but notes were taken. The notes can be found in Appendix A. Our roles were either that of the interviewer or the note-taker. Through the use of Google Docs and two laptops we were able to switch these roles dynamically as the interview progressed. After these interviews we discussed the interview and grouped the notes per topic.

Since the interviews were part of the stage of the initial exploration of work (Spinuzzi 2005) they had the form of open conversations. These conversations were started by an introduction of our project and the interviewee’s initial reaction from the perspective of their particular specialization (See appendix A). Based on this reaction we progressed the conversation and deepened the understanding of the exposed topics with questions. I deliberately structured the interviews like this since each interviewee came from a unique field of specialization and there was no effective benefit a standard interview format from which we could have rigorously triangulated the results. Instead, such a format would most likely have obstructed the explorative process.

However, there was a recurrence of four basic topics that were brought forward by each of the interviewees. These discussed topics were:

- Desired use cases
- Stakeholder relations
- Values
- Service elements

I organized the individual interviews per topic. These can be found in Appendix A. For this thesis these findings are grouped per topic and triangulated. The key findings that were brought to light are discussed in chapter 4.

Co-design Sessions
Five co-design sessions were held with five separate makers representing important user groups. The goal of these sessions was twofold, firstly to understand the existing behavior of the makers, and secondly to reveal their thoughts and needs concerning the tools for collaboration and documentation. All the co-design sessions were captured on video after getting consent. These videos were not transcribed, but used to provide clarity on parts of the written documentation created during the co-design sessions during the analysis.

In the first stage of the co-design sessions we focused on the maker’s activities regarding documentation and communication during their projects. To openly take notes I created a form on which the notes could be quickly jotted down during the conversation. Figure 8 shows a filled out form. Any information we received on what the maker project constituted was written down into the upper right corner. Anything related to communication during these projects was noted into the lower right corner. All the remarks
made related to documentation were placed on the left. Because of the at times progressive nature of the conversation and the caused ambiguity in the data there were spaces included on the form where these areas overlapped.

The second stage of the co-design sessions began with a summary of the forms from the first stage. This helped to make and reflect assumptions together with the makers. As discussed earlier this was important since we did not apply rigorous ethnographical methods. It additionally helped the makers to reflect and become aware of their behavior.

The second stage proceeded with an exercise in designing and sketching elements of tools that the participant believed would be useful. This included designs for interfaces, interactions and functionality. Thinking about and discussing imagined solutions helped to define the problems and contexts of the makers. The exercise was done on A1 sized sheets of paper that were spread out on the table between the interviewee and interviewers. On these sheets notes and sketches were made collaboratively with the maker, giving them a sense of ownership and connection with the design.

The findings from the co-design sessions were extracted from the forms and the sketches made during the two stages of the sessions. These findings can be found in Appendix B. In this thesis these findings form a base for personas that are discussed in chapter 4, which will be used to create design directions in chapter 5.
**Evaluating the first prototype**

The first prototype was created to guide conversations with makers in such a way that design decisions could be validated. By presenting this prototype on booths on two public events, the Maker Faire in the UK and the Demo Day in Aalto’s Media Lab, the implemented findings from the previous research were evaluated by a plethora of makers. The variety of people and their unique contexts formed the basis for an interpersonal assessment of the application and its goals. However, because of the highly personal character of a booth presentation it was also possible to profile and understand several types of makers. The one-on-one talks with makers allowed us to review the expected benefits and drawbacks of our application in detail by relating to their individual practice. Any observations, citations and summaries of conversations were written down in notebooks either during or directly after the conversations.

Various materials that supported and aided the presentation of the prototype accompanied the booths. A large poster “pitched” several advantages the app could provide makers to grab the attention of passing visitors. Smaller posters invited people to pick up one of the three mobile devices on which we had installed and opened the application, so they could try the application for themselves. A projected video showed how to use the application in a filmed example project.

The description of the first prototype can be found in appendix C. The documentation of the events, as well as the retrieved feedback is written down in appendix D. Chapter 6 first elaborates the design of the application and later discusses the findings of the evaluation.

**Usability tests with the second prototype**

After the evaluation of the first prototype the design has been revisited and improved. The prototype was then significantly changed. Unfortunately not all the designed improvements could be implemented in the available time. However, this second prototype was still fit for usability testing.

A program for a series of usability tests was structured based on the workflow described in Carolyn Snyders book on usability tests with paper prototypes(Snyder 2003). Although the prototype that would be used in this project was much further developed than a paper prototype, thanks to the currently available prototyping and rapid development environments, the described structure of a usability test has kept its relevance over the years.

Three usability test sessions have been conducted in collaboration with the Fab Lab in Aalto University’s Media Factory. A total of five test subjects participated. One test session was completed individually while two other sessions invited a pair of subjects in a co-discovery process. All subjects were representative of one persona group, and were invited to complete three tasks that related to typical use cases for that group.

The structure for the individual and co-discovery tests were slightly different but addressed the same tasks. The first task was an introductory task, meant to allow the subjects to explore the application and its functionality, and clarify the expected activity in the later tasks. For this an example log in which the functionality of the application was demonstrated was prepared. The subjects were invited to document
pictures and text in the log while practicing the thinking aloud method. The task ended with the user creating their own log for documenting the activity of the following tasks.

The second task challenged the subjects to educate themselves on 3D printing processes and explore 3D printer software. This was an area of expertise that was new for all subjects. The task ended with the subjects printing a 3D model of a Labrador. This complex process could be completed after combining knowledge available in a printed booklet and a log in the application. The challenge was to structure explicit knowledge derived from a variety of media, apply this knowledge, and document these processes.

The first session asked an individual subject to complete the second task. The third session allowed two subjects to attempt it in a team effort. The second session was the most challenging and invited two subjects to complete the task while communication through the collaborative features of the application.

After task two the subject(s) received a printed 3D model of the Labrador. I had prepared these printed Labradors beforehand and had left all the support materials that were needed to properly print these sculptures. The third task invited the subjects to “clean up” their Labradors by carefully removing these supporting structures. During this activity with the new material the subjects dealt specifically with tacit knowledge.

During the first two sessions the subjects were not given any directions on how to do clean their labrador. They were asked to document this explorative physical activity. During the third session the subjects were allowed to look into the documentation made in the previous sessions. In summary, the third task was intended to explore the documentation of physical processes with the application, as well as testing the communication of tacit knowledge across sessions.

I introduced the tasks to the subjects, and wrote down observations and comments by the subjects that were thinking aloud during the tests. Because of the complexity of the tasks not all the thoughts and actions of the subjects could be captured. This is why short follow-up interviews were held to expand understanding of their experiences.

The list of changes made to the first prototype can be found in Appendix E. These changes are more thoroughly described in chapter 7. The detailed task descriptions, task materials and user feedback can be found in Appendix F. The key findings and limitations of the test results are also discussed in chapter 7. Chapter 8 finalizes the research through design part of the thesis by identifying three UX themes.
PART II: RESEARCH FOR DESIGN

3. LITERATURE REVIEW
MAKERS
MAKER SPACES
INNOVATIVE COMMUNITIES
KNOWLEDGE EXCHANGE IN COLLABORATION
INFRASTRUCTURE
MAKERS

Defining DIY and making

Let’s take a closer look at what DIY activities encompass. Wolf and McQuitty defined them as “activities in which individuals engage raw and semi–raw materials and component parts to produce, transform, or reconstruct material possessions, including those drawn from the natural environment (e.g., landscaping).” (M. Wolf and McQuitty 2011). This is commonly understood as “creation, modification or repair of objects” (Mota 2011; Kuznetsov and Paulos 2010). Mota adds that DIY practices lie outside of an individual’s professional expertise (Mota 2011). While Kuznetsov et al emphasize that these activities are taking place without the aid of paid professionals (Kuznetsov and Paulos 2010). In this thesis these definitions are compounded and DIY activities are understood as self–reliant and non–professional activities involving the creation, modification, or repair of possessions whilst utilizing raw or semi–raw materials, or component parts.

This understanding of DIY incorporates traditional making practices, which are present throughout human history (Kuznetsov and Paulos 2010), but it also leaves room for the modern connotation of the term that involves hi–tech materials and tools. The modern meaning of DIY relates to a model for technological innovation by hobbyists. It has been popularized and labeled as “making” by Make Magazine in the US (Eychenne 2012). A steady increase in accessibility to both tools and information over the past few decades have spurred interest and participation in such DIY activities as well as the term “maker” (Paulos 2013; Grimme, Bardzell, and Bardzell 2014; Kuznetsov and Paulos 2010; Mohomed and Dutta 2015). Although some literature distinguishes “making” from DIY (Grimme, Bardzell, and Bardzell 2014) these terms are more often used interchangeably with each other, with “makers” generally referring to people engaged in DIY practices. In continuance with this practice this thesis will also refer to DIY activities as making.

Making as empowering activity

Grimme et al identified key differences between “made” and “designed” objects (Grimme, Bardzell, and Bardzell 2014). They state that made objects are “more a technology of the self” than products intended for the market. But also note that making is an inherent critical activity because of its focus on the shortcomings of consumerism. According to them the act of revoking a product’s or service’s finished status moves the consumer into an empowered position, the one of a maker (Grimme, Bardzell, and Bardzell 2014). This notion of individual empowerment and the turn from passive consumer to active participant through innovation has been substantiated by other research (Ames et al. 2014; Lindtner, Hertz, and Dourish 2014; Hippel 2006). Grimme et al contribute to this body of research by elaborating three themes of empowerment within making communities (Grimme, Bardzell, and Bardzell 2014):

- Empowering oneself
  Artifacts and activities that allow a subject to shift from being a passive consumer towards being an agent over their own possessions. Maker practices in this category are often motivated by the desire to learn new skills, to satisfy a need for a solution, or to be productive. Only few making practices were found to be overly politically motivated yet sustainability, self–sufficiency, recycling and reusability were passionately mentioned as motives.
• Empowering others
  Artifacts and activities that raise awareness or affect changes toward social issues or encourage, educate and inspire others to make for themselves. Makers demonstrate making is within anyone’s grasp by sharing their projects and processes.

• Empowering making communities
  Artifacts and activities that contribute to the networks and resources of the maker community. Through sharing their tools, plans, processes and projects makers can discover and shape social structures that support making.

The three themes of empowerment give general directions on how the activity of making and made artifacts empower (Grimme, Bardzell, and Bardzell 2014). However, they do not provide a satisfactory explanation on how that empowerment is achieved. The research conducted by Toombs et al provides that explanation by focusing on the identity formation processes of makers (Toombs, Bardzell, and Bardzell 2015).

Identities in the making

In their study Toombs et al provide detail to the general idea of what a maker is by introducing the concept of different degrees of “maker-ness” (Toombs, Bardzell, and Bardzell 2015). They point out the frequency of participating in DIY activities affects the maker’s level of establishment. An established maker regularly takes part in DIY activities, while others might only incidentally participate. After researching the gradual evolution from one degree of maker to another they present three main concepts central to the formation of a maker identity (Toombs, Bardzell, and Bardzell 2015). These are:

• Developing a sensibility for tools and materials
• Cultivating an adhocist attitude
• Attaining a sense of engagement with the maker community

According to their study one way for established makers for prove themselves as such is by showcasing the ability to make a self-made tool. To reach that level a maker has to obtain experience in two of the three characteristics that will define an identity as a maker. First the maker must recognize tools and materials as extensions to human capabilities, which require changes in behavior, imaginative skills and judgment to be used well. Understanding tools in this way reveals the necessity to develop a deep familiarity with tools and materials. Makers generally gather familiarity with a variety of tools and materials, which provides them with a so-called tool and material sensibility. This sensibility empowers them to envision and pursue new DIY activities (Toombs, Bardzell, and Bardzell 2015).

Secondly, makers need to cultivate an adhocist attitude. Having an adhocist attitude implies having enough confidence to rely on the application of your tool and material sensibility to solve problems whenever they arise. The attitude allows makers to accept making as a dependable method for continuous progression within a project. In other words, this approach enables makers to be less concerned with planning and instead iterate homemade solutions. This iterative process propagates a maker’s tool and material sensibility, advancing the degree of their maker-ness (Toombs, Bardzell, and Bardzell 2015).

A self-made tool can be only be made when sufficient tool and material sensibility and adhocist attitude have been gained. The maker needs to deeply understand existing tools and their limitations, and be
confident enough to improve on them or create a new tool altogether. The self-made tools that Toombs et al. encountered in their study were rarely perfect. However, they were optimum for the maker’s context and allowed them to activate their intuition and imagination in unique ways. The researchers continued discovered that the tools went beyond being mere artifacts by becoming representative of the maker’s creativity, individuality and self-expression. This formed the basis for intimate relationship between the tools and their users (Toombs, Bardzell, and Bardzell 2015). Similar relationships have been pointed out in other research (Kuznetsov and Paulos 2010; Golsteijn, van den Hoven, et al. 2014; McKay et al. 2015).

The third main concept presented by Toombs et al. says that makers need to be engaged with the maker community. Their research took place in a hackerspace, a space which provides makers with tools and materials, but also a social environment they described demonstrated “a clear acceptance of failed projects as a legitimate and necessary form of practicing one’s skills.” (Toombs, Bardzell, and Bardzell 2015). The hackerspace facilitated the identity formation process by allowing makers to exchange knowledge to develop their sensibility and attitude. This thesis investigates such facilitation of knowledge sharing, and will therefore continue in the next chapter with a more extensive research on the different maker spaces.

**KEY FINDINGS**

- **DIY activities** are self-reliant and non-professional activities involving the creation, modification or repair of possessions whilst utilizing raw or semi-raw materials or component parts.
- “**Making**” refers to DIY activities, and “**maker**” to a person engaged in DIY activities.
- A recent increase in accessibility to tools and information has spurred interest and participation in making.
- The act of making can be understood as social criticism within the current economical context.
- **Making can be used to empower oneself, others and the development of making communities.**
- There exist degrees of “**maker-ness**” and makers gradually progress from one degree to another.
- **Becoming deeply familiar with different tools and materials develops a tool and material sensibility.**
- A tool and material sensibility empowers makers to envision and pursue new DIY activities.
- An **adhocist attitude enables makers to rely on their making practices to iterate solutions.**
- **Makers form their identity by utilizing and developing their tool and material sensibility, adhocist attitude, and the creation and use of self-made tools.**
- **Makers engage in creating maker communities because those facilitate the identity formation processes of makers.**
MAKER SPACES

What is a maker space?
As was mentioned in the previous chapter, maker spaces facilitate the identity formation of makers and that is why makers engage the creation of them. Since a maker identity involves developing a tool and material sensibility maker spaces are naturally required to provide access to tools and materials. But just providing access to the tools is not enough, makers need to be able to become familiar with the tools and cultivate an adhocist attitude. This is why maker spaces usually contain an infrastructure for knowledge sharing or education.

With all things considered, the maintenance of a maker space is a very costly and labor-intensive project (Eychenne 2012). There are many kinds of maker spaces, ranging from small private spaces to large public spaces. Some types of maker spaces form networks while others choose to stay independent. Although no two maker spaces are the same, they are mainly organized according to one of four models in order to guarantee their continued existence. These models are:

- Commercial maker spaces
- Academic maker spaces
- Community driven maker spaces
- Maker spaces with governmental support

In this chapter these models will be discussed by describing popular examples for each of them.

Commercial maker spaces

Introduction
The most well-known instances of commercial maker spaces are part of the Techshop franchise. Techshops are membership-based, privately owned workshops providing a wide array of tools for personal digital fabrication. Although they do not discriminate on skill level, Techshops tend to target the more established makers and professional artists, entrepreneurs, and designers that do not have access to a private workshop (Mota 2011; Eychenne 2012). Members do projects for commercial application, for instance to create rapid prototypes for market testing or to produce limited editions of products (Eychenne 2012).

Tools and materials
Techshops are the largest and most well equipped forms of maker spaces with both advanced digital (e.g. 3D-printers, laser cutters, etc.) and analog (e.g. milling machines, hydraulic presses etc.) tools available. Because of their size and offering maker spaces like Techshops require the largest initial investment of all the maker space models. Opening a space such as the Techshop in San Francisco would require around $2.5 million, which causes owners to heavily rely on investors (Eychenne 2012). At the time of writing there are 8 Techshops active and two more are planned, all in the US (“Techshop Locations” 2015). To make the opening of a Techshop more accessible Techshops offers a “Techshop Academy” program. This program educates potential founders how to construct and operate a maker space based on the Techshop model (“Techshop Academy” 2015).
Education
Techshops provide high quality paid services for education and consultation. These are either delivered personally or in courses ("Techshop Classes" 2015; "Techshop Personal Services" 2015). Eychenne observed that Techshops also function as places for networking and meeting other members (Eychenne 2012). Although he did not mention anything about the knowledge exchange between Techshop members, their commercial goals give reason to believe that there is at least some need for keeping secrecy.

Academic maker spaces

Introduction
Academic maker spaces are spaces connected to university funding. The MIT Fab Lab is the most famous example of these types of spaces since it played an important role in the early stages of the maker space development (Gershenfeld 2007). The first Fab Lab was part of MIT’s CBA (Center for Bits and Atoms). The CBA intended to create a learning ground for digital and personal fabrication. Through the use of the Lab they attempted to empower consumers and democratize technology and techniques (Eychenne 2012). These goals have continued to shape other Fab Labs by the creation of a Fab Charter ("The Fab Charter" 2015) which defines what a Fab Lab is and does.

The first series of Fab Labs opened in 2002 (Kohtala and Bosqué 2014) and their number has steadily increased since then. Now, in 2015, over 500 spaces are registered as Fab Labs on their website ("List of Fab Labs" 2015). Throughout the expansion of the Fab Lab network the values described in the charter have somewhat changed, but remained true to the core idea of democratizing fabrication. Much research indicates that these values are reflected in Fab Labs (Eychenne 2012; Kohtala and Bosqué 2014; P. Wolf et al. 2015; Troxler and Zijp 2013). In the Fab Labs the standard that access to machines and knowledge must be free to a certain extent, and members should share their knowledge with others in return is maintained (P. Wolf et al. 2015) (Kohtala 2013). Fab Labs organize access to materials, but members should still pay for what they use.

Tools and materials
Projects in Fab Labs are intended to supply members with the skills needed to become “inventors” of their own technology (Gershenfeld 2007). This usually involves members creating a single or a limited number of objects, either individually or with a group (Eychenne 2012).

The tools in a Fab Lab are meant to be “extensions of the internet” and are thus digital tools. In order to carry the “Fab Lab label” a Fab Lab needs to be equipped with a minimum set of required tools specified by MIT (Eychenne 2012) (“What Is a Fab Lab?” 2015). This set includes a laser cutter, CNC milling machine, 3 axis router, vinyl cutter and a 3D printer (“Setting up a Fab Lab” 2015).

Education
The organizations providing the financial support a Fab Lab needs shape its ‘general color’ (Eychenne 2012). Several Fab Labs are connected to university funding and fit the academic maker space model. The remaining Fab Labs carry characteristics found in the other models discussed in this chapter and will be discussed in 2.2.2.5. Academic Fab Labs are mainly intended to support the learning practices of the students in the universities. But since openness is compulsory for Fab Labs according to the charter,
these Labs organize “Open Lab”-days on which they grant free access to the space and tools for the general public (Eychenne 2012; “What Is a Fab Lab?” 2015).

Educational activities in any Fab Lab involve courses on how to use tools and materials, which in the academic Fab Lab are free for students. But there is also an existing fondness for P2P learning, which is stimulated by the staff members (Eychenne 2012).

**Community driven maker spaces**

*Introduction*

Community driven maker spaces rely completely on the contributions of its members. The most emblematic examples of these spaces are the so-called hackerspaces. Hackerspaces have their roots in the 1960s counter-culture movements (Eychenne 2012). The first hackerspace opened in 1995 which increased to 500 in 2010, but at the time of writing there are over 1900 hackerspaces registered (Lindtner, Hertz, and Dourish 2014; Ames et al. 2014; “List of Hackerspaces” 2015) which indicates an accelerated growth.

Hackerspaces are laboratories for grassroots organisations that sprout from local communities. They focus on peer learning, collaborative problem solving, and community building. Founders and members see hackerspaces as “emerging sites of innovation, research and development” (Lindtner, Hertz, and Dourish 2014). Inside hackerspaces there is no clearly defined leadership. Hackerspaces exist in great variety because of the diversity of their core communities and their specific needs. In between them is a loose network of connections, but all the hackerspaces act independent from each other (Mota 2011). This is very different from Fab Labs or Techshops, in which leadership roles are clearly defined and networks are strong enough to carry through standards across makerspaces.

*Tools and materials*

There no standards for available equipment in Hackerspaces, instead the community decides what it wants to invest in and what it can afford. Although laser cutters, 3D printers, and open microcontroller platforms are usually present these are by no means required. In practice the selection of tools varies greatly between individual hackerspaces (Mota 2011; Lindtner, Hertz, and Dourish 2014).

*Education*

Knowledge exchange in hackerspaces is purely depending on peer learning (Mota 2011). Many active members are established makers and thus value supporting their maker community. Eychenne notes that this high level of expertise and focus on the group may appear intimidating for new members (Eychenne 2012).

**Maker spaces with government support**

*Introduction*

The capacity of maker spaces to stimulate education and involvement with technology has been noticed by various governments. For instance China has founded national maker spaces which are accessible to
all citizens (Lindtner, Hertz, and Dourish 2014). In the northern hemisphere governments might partially or completely fund maker spaces to promote access to tools, practices and existing culture of digital collaboration. On the southern hemisphere maker spaces are generally fully funded by governments and are meant to anticipate on local demands and encourage local skills (Eychenne 2012).

**Tools and materials, and education**
The supplied facilities vary between these spaces, if a government partially funds a Fab Lab in order to stimulate more “Open Lab”-days there will be a Fab Lab set-up. But if the government supports a hackerspace or creates an independent makerspace the infrastructure can differ to a great extent.

**Cross-overs**
Many maker spaces fit into more than one of previously discussed categories and share characteristics from multiple models. For instance, a Hackerspace could be partially supported by school funds, or a private investor could provide for a Fab Lab. This causes variation in the organization of a maker space and its activities. Figure 9 shows from which model the example maker space chains could borrow elements.

Figure 9. An overview on which models the example maker spaces might base themselves.
Shaped by the community

The hackerspace Toombs et al described (Toombs, Bardzell, and Bardzell 2015) provided the makers with a social environment that allowed makers to develop their identity. Mota identifies that this is mainly facilitated through peer learning (Mota 2011). Lindtner et al point out that hackerspaces emerge from local communities (Lindtner, Hertz, and Dourish 2014). As stated before, these communities are able to shape their hackerspaces according to their demands, leading hackerspaces to differ greatly from each other. But more importantly as Kohtala et al (Kohtala and Bosqué 2014) (Kohtala 2013) reveal in their research, the communities themselves constitute the primary instrument that allows makers to solve their local and situated problems. Toombs et al substantiate this finding and affirm that the physical infrastructure in a maker space exists in order to cultivate the desired social environment (Toombs, Bardzell, and Bardzell 2015).

In the next chapter these communities will be identified as communities of practice. Identifying them as such helps to build an understanding in what manner these communities facilitate makers to learn and innovate.

KEY FINDINGS

- Setting up and maintaining a maker space is very costly, making organizational structures a common concern.
- There are four main organizational models for maker spaces that are either applied in pure or hybrid configurations.
- Commercial maker spaces provide tools for a professional target group, requiring them to be well equipped and costly.
- Knowledge exchange in commercial maker spaces is mostly depending on paid services and educational programs.
- Academic maker spaces focus on the democratization of fabrication by providing access to tools and education to students.
- Knowledge exchange in academic maker spaces consists of offered courses and peer learning.
- Community driven maker spaces are sites of innovation, research and development emerging from and supported by communities.
- Knowledge sharing in community driven maker spaces relies on peer learning.
- Government supported maker spaces aim to stimulate education and involvement with technology and provide public access.
- Government supported maker spaces might either offer educational programs or rely on peer learning or do both.
- Maker spaces exist in order to facilitate a social environment and community that enables makers to progress as makers.
PART II.

INNOVATIVE COMMUNITIES

Maker communities of practice

The previous chapters frequently mentioned the word community. We find the common understanding of community in our context reflected in Kuznetsov’s formulation “a group of people who share common goals and interests- communicating through mediums online and in person.” (Kuznetsov and Paulos 2010). We have seen that communities in maker spaces are primarily engaged in processes of developing their abilities by learning with and from each other. If we compare these two observations with the definition of a community of practice “A community of practice is a group of people who share a concern or a passion for something they do, and learn how to do it better as they interact regularly.” (Team BE 2015) we can easily discover the resemblance between them. According to Wenger (Team BE 2015) a community qualifies as a community of practice when they possess these three key elements:

- Members are brought together by a learning need they share (the domain)
- Their collective learning becomes a bond among them over time (the community)
- Their interactions produce resources that affect their practice (the practice)

We have previously seen that to facilitate their learning process makers meet online and in maker spaces (the domain). We’ve found that they create lasting networks (the community), and that interactions such as P2P learning influences their activities (the practice). Thus we can consider maker communities as communities of practice.

By identifying maker communities as communities of practice we accept that learning is a core value of these communities. Johnson (Johnson 2001) notes that learning in communities of practice can be distinguished from traditional learning situations in three ways:

- Different levels of expertise are simultaneously present in a community of practice
- Fluid peripheral to center movement that symbolizes the progression from being a novice to expert
- Completely authentic tasks and communication

He also conveys that these learning practices are including aspects of constructivism, and involve community knowledge that is greater than individual knowledge and an environment of safety and trust (Johnson 2001). Wenger refers to this type of learning as “Situated learning” (Lave and Wenger 1991).

According to Johnson’s research (Johnson 2001) constructivist learning involves:

- **Ill-structured problems**: complex and messy problems as they are found in realistic situations.
- **Collaboration in social and physical context of problems**: to solve ill-structured problems collaboration with people with different skills, experience and backgrounds is necessary. Following this it can be noted that in communities of practice the collaborative knowledge of the community is bigger than any individual knowledge.
- **Negotiated goals**: through negotiating goals learners establish ownership over processes, which increases interest and learning.
- **Cognitive tools**: learners use processes, procedures and technology for organizing knowledge.
- **Instructors as facilitators**: Ill-structured problems are problems for which no specific knowledge
or mastery is available, in this context instructors take on a guiding role for aiding learners to
develop learning strategies. In practice these so-called facilitators fine-tune and nudge discussion
in the right direction, emphasizing the creation of goals and criteria for meeting goals, evaluation of
whether goals have been met, and evaluation of peers and oneself (Johnson 2001).

Through understanding makers as part of communities of practice we can begin to discover directions for
design. To elaborate, we find that makers deal with ill-structured problems, requiring them to collaborate
and negotiate. Additionally, tasks and communication become completely authentic. Authentic tasks
demand collaborations between makers with different expertise and level of skills, as well as the learning
of exchanged skills. This learning necessitates facilitators and the creation of cognitive tools. Thus
design for facilitation of knowledge exchange between makers could be guided by lessons learned from
facilitators and existing cognitive tools in communities of practice.

One thing that the facilitators and cognitive tools have in common is that they provide supportive
infrastructure for what Johnson (Johnson 2001) refers to as “fluid peripheral to center movement”. This
development of makers from being a novice (at the periphery) to an expert (in the center) is done through
locating expertise and resulting mentor-apprentice relationships (Johnson 2001). Mentors take the role
of an instructor if they have adequate expertise, or a facilitator if they don’t. In the next paragraph we
will take a closer look at what the function of a mentor is a community of practice.

Leadership in communities of practice

Pace et al. (Pace et al. 2013) mention in their research on leadership in the Etsy community that Etsy
habitually promotes certain users to be featured sellers in order to form a leadership-by-example
structure. The Etsy organization feels it is important that users are able to read the stories of their
featured sellers in order to portray the community vision and ethos (Pace et al. 2013). Hogg and Reid
(Hogg and Reid 2006) understand community vision and ethos as norms, and point out that from a social
identity perspective norms reflect a group prototype. They explain that leaders that fit a group prototype
will be more influential than a leader that does not. They give five reasons:

• Follower behavior conforms with the leader’s behavior
• Followers see their wishes reflected on a higher status position
• Prototypical leaders identify strongly with the group and behave in group-oriented and group-
serving ways.
• Prototypical leaders build trust with their group-oriented behavior, allowing the changing of norms.
• Prototypical leaders become the focus of the group because members feel they are the best source of
information in the group (Hogg and Reid 2006).

At the base of these thoughts lies the assumption that:

• Norms are fluid, context dependent representations that position the group in relation to other
groups.
• Norms are changed and maintained through communication and internalized by group members
through group prototypes (Hogg and Reid 2006).

In conclusion we can say that for norms to be established and be obtained by members there is a need for
group prototypes, which can be embodied by leaders. In communities of practice the concept of a leader is depending on the context of the ill-structured problem, in which mentor-apprentice relations appear. Setting and communicating the norms in a community of practice can be understood as done by mentors.

Shared norms are identified by Meyer (Meyer 2003) as fundamental for social networks engaged in a process of collective invention. A process he shows has had its recurrence in history (Meyer 2003).

**History and future of collaborative innovation**

Meyer (Meyer 2003) defines collective invention as “a process in which improvements or experimental findings about a production process or tool are regularly shared.”. He further states that collective invention happens in episodes at the beginning of the development of new technologies. He divides such a wave of invention into six periods in which:

- a new opportunity is introduced
- interested parties are aware of the uncertain potential
- social networks for collective invention form
- hobbyists and firms create micro-inventions
- firms seize the opportunity for profit
- collective invention evaporates and surviving firms continue running private research (Meyer 2003)

More importantly, he points out that collective invention includes a clear sharing phase, in which documented technical discussion is being shared freely. He hypothesizes that without this sharing phase various technologies might not have been developed to a point of carrying benefit for the society.

Baldwin and Von Hippel (Baldwin and Von Hippel 2010) substantiate that claim, and show that DIY practices have significantly modified and influenced commercial product and process development across fields (Baldwin and Von Hippel 2010). Von Hippel (Hippel 2006) identifies an ongoing process called “user innovation” in which DIY innovations by users are fed back into the supply network (Hippel 2006). Raasch and Von Hippel (Raasch and Von Hippel 2012) demonstrate that products that are complemented by user innovations carry more value for the user, and that an increase in DIY users causes a market to be more competitive and thus more efficient (Raasch and Von Hippel 2012). Baldwin and Von Hippel (Baldwin and Von Hippel 2010) conclude that two forms of user innovation increasingly compete with and could eventually partially displace traditional innovation structures in various fields. This increasing competition they state is caused by a transition to digitized and modular design and production, combined with accessible, low-cost communication. According to their research the forms of user innovation are:

- **Single User Innovation**: A single user or firm innovating for own use. Applicable when design costs are low. Projects like these commonly originate from necessity of the user (Hippel 2006; Liedtka 1999; Hyysalo and Usenyuk 2015; Baldwin and Von Hippel 2010).
- **Open Collaborative Innovation**: Innovative designs generated collaboratively by participants without commercial purpose. Projects with high design costs can be achieved, but only when the design can be separated into modules and communication costs are low (Baldwin and Von Hippel 2010).
Of these two forms the study expects open collaborative innovation projects to cause a bigger positive impact to traditional innovation structures. But for these projects to emerge it must be possible to organize the work in modules, so tasks can be done independently and in parallel. Also, it is necessary to lower the costs of communication to stimulate participants to contribute and reciprocate (Raasch and Von Hippel 2012).

Hyysalo, Johnson and Juntunen (Hyysalo, Johnson, and Juntunen, n.d.) show that frequently used communication platforms can provide users with directions for search and solutions even with physical products which cannot be shared digitally. However, according to their research these platforms do not support the creation of modular solutions, clear instructions, and activities related to customization (Hyysalo, Johnson, and Juntunen, n.d.). Since it can safely be assumed that the maker community possesses the technical expertise to create modular designs, the crux of the problem might lie in the lacking capacity of the communication platforms to facilitate the needed types of discussion for such designs. A comparable situation might cause the inability to create clear instructions and customization activities. To find directions on how to facilitate such communication we will take a closer look into the knowledge exchange in collaborative practices.

**KEY FINDINGS**

- **Maker communities are communities of practice brought together by a need to solve ill-structured problems.**
- **Mentors-apprentice relationships are formed to facilitate periphery to center movement needed to solve ill-structured problems.**
- **To move from the periphery to the center there is a need for collaboration, negotiation and cognitive tools.**
- **Norms are fluid and context dependent representations used to position a group in relation to others. They are changed and maintained through communication and internalized by group members through group prototypes.**
- **In maker communities mentors reflect the group prototypes and thus set and communicate the norms.**
- **DIY practice can be part of an episode of collective invention, which takes place in the early development of new technologies and thrives on sharing of information.**
- **Collective invention and user innovation have significantly influenced commercial product and process development.**
- **Both Single User Innovation and Open Collaborative Innovation positively influence the traditional innovation structures.**
- **Open Collaborative Innovation projects carry a lot of potential but are only feasible when design can be separated into modules and communication costs are low.**
- **Current communication platforms are not optimal for facilitating Open Collaborative Innovation projects.**
KNOWLEDGE EXCHANGE IN COLLABORATION

Developing and sharing knowledge

In maker communities of practice collaboration plays a central role in identity formation processes. To understand what happens during collaboration we first examine the definition. In the Oxford Dictionary collaboration is understood as "the act of working with another person or group of people to create or produce something"(“Oxford Advanced Learner’s Dictionary” 2015). Collaboration can thus be understood as a shared creative process revolving around a shared goal. Roschelle and Teasley (Roschelle and Teasley 1995) distinguish between cooperation and collaboration. Cooperation is a process based on division of labor, while collaboration is a coordinated effort to solve a problem together (Roschelle and Teasley 1995). In our case these problems that are solved together are ill-structured problems.

To solve ill-structured problems a certain level of creativity is needed. In their research on creative design, Dorst and Cross (Dorst and Cross 2001) identify a process of exploration that involves the co-evolution of a problem and a solution space. In their words this process involves “refining together both the formulation of a problem and ideas for a solution, with constant iteration of analysis, synthesis, and evaluation processes between the two notional design ‘spaces’ – problem space and solution space.” (Dorst and Cross 2001). This is illustrated in Figure 10.

![Figure 10. Co-evolution of problem-solution by Dorst and Cross (Dorst and Cross 2001)](image-url)

By structuring the initial problem space P(t) the designers discover P(t+1). P(t+1) is the base of the then partially structured solution space S(t), S(t+1). By expanding on S(t+1) they formulate S(t+2), which then informs P(t+2)(Dorst and Cross 2001). It is clear that this process of incrementally structuring both the problem space and the solution space could be utilized for finding a fitting problem-solution pair for an ill-structured problem.
Wang, Cosly and Fussell identify collaboration as a useful way to approach creativity (Wang, Cosley, and Fussell 2010) because it expands an individual’s limited vision, knowledge, experience, motivation and time (Wang, Cosley, and Fussell 2010). Leonard and Sensiper (Leonard and Sensiper 1998) conclude that many creative individuals are aware of the profound social nature of their creative process. They also point out that social interaction is especially important for individuals delivering new products, services, and organizational processes (Leonard and Sensiper 1998). In other words, collaboration is recognized to improve the co-evolution of problem and solution spaces by sharing perspectives. But linked to this, Martin, O’Neill, and Randall (Martin, O’Neill, and Randall 2009) point out, is the discovery that design teams build up a discourse during a design process (Martin, O’Neill, and Randall 2009).

Roschelle and Teasley (Roschelle and Teasley 1995) support this finding and state that collaborative problem solving consists of two activities: solving the problem together and building a Joint Problem Space (JPS). A JPS, they elaborate, is a pragmatic, shared knowledge structure that assists the problem solving activity in collaborations. A JPS integrates:

- Goals
- Descriptions of the current problem state
- Awareness of available problem solving actions
- Associations that relate goals, features of the current problem state, and available actions (Roschelle and Teasley 1995).

We can recognize that the JPS contains a shared understanding of the co-evolving problem–solution pair. Roschelle and Teasley point out that to construct a JPS, participants need ways to:

- Introduce and accept knowledge into the JPS
- Monitor on-going activity for evidence of divergences in meaning
- Repairing divergences that impede progress of the collaboration (Roschelle and Teasley 1995).

They conclude that successful collaboration presupposes that participants make conscious and continuous attempts to organize language and activity in regards to shared knowledge (Roschelle and Teasley 1995). Related to this, Vyas, Heylen, Nijholt, and Van der Veer (Vyas et al. 2009) find three surprising themes in the process of developing of a JPS between designers, which are:

- Externalization, the use of three dimensional artifacts to establish common ground
- Use of physical space, an ecological set-up with artifacts that aid the organization, coordination and management of the work
- Use of body, for communication and exploration of knowledge (Vyas et al. 2009)

These are three themes that indicate that in the context of creating physical artifacts knowledge exchange cannot rely purely on codified knowledge but also involves transfer of tacit knowledge. Previously it was mentioned that this tacit knowledge hindered the documentation of maker projects (Kuznetsov and Paulos 2010; P. Wolf et al. 2015). Since documentation plays a central role in collaboration and communication between makers (P. Wolf et al. 2015; Hyysalo, Johnson, and Juntunen, n.d.) it is important to get a clear understanding of what tacit knowledge transfer encompasses.
Tacit knowledge conversion

Nonaka and Von Krogh (Nonaka and von Krogh 2009) distinguish between defining knowledge as representations of a pre-given reality and knowledge as justified true belief. The latter definition implicates that “beliefs come true if they can be justified and are useful to the individual or group in question, and enable this individual to act, the group to coordinate individual action, and shape ‘reality’” (Nonaka and von Krogh 2009). Understanding knowledge in such a way allows the inclusion of tacit and explicit forms of knowledge.

Knowledge that is articulated and can be captured in artifacts such as writings and drawings is explicit, also referred to as codified. Explicit knowledge is formal, systematic and communicates clearly. For instance formulas, computer programs, presentations, or technical specifications are explicit knowledge. Knowledge that is highly personal, tied to senses and unarticulated mental models is tacit, sometimes mentioned as implicit. Tacit knowledge is procedural, practically useful and intuitive. It is sometimes referred to as tacit skills to emphasize its physical character. Because tacit knowledge is being embodied it is below the level of awareness and thus escaping any formal analysis through self-introspection (Nonaka and von Krogh 2009; Polanyi 1966; Holste and Fields 2010; Rangachari 2009).

Polanyi (Polanyi 1974) discerns between subsidiary and focal awareness. Focal awareness is the object of ones conscious attention; subsidiary awareness is created when something that demanded focal awareness has lapsed into unconsciousness. This lapse into unconsciousness allows tools to become used effectively as instruments through which we act without demanding our attention. These forms of awareness are mutually exclusive he states, meaning we cannot be both focally and subsidiary aware of something (Polanyi 1974). Tsoukas’ aptly describes this as “a person cannot be simultaneously be aware of the task and the tool” (Tsoukas 2005). The difficulty of articulating tacit knowledge lies in that we need focal awareness to describe that which we can only be subsidiary aware of.

However, some believe that the relationship between explicit and tacit knowledge is not completely dichotomous, but more fluid. One shared perspective on knowledge accepts this relationship as a continuum, having tacit and explicit on either side and degrees of tacitness in between (Jasimuddin, Klein, and Connell 2005; Ambrosini and Bowman 2001).

Although some researchers claim that all tacit knowledge can be converted into explicit knowledge (Desouza 2003) others maintain that it can never be converted, but only displayed in actions (Tsoukas 2005). A more nuanced understanding of conversion can be found in Ambrosini and Bowman’s research (Ambrosini and Bowman 2001) that maps out the range of tacitness of knowledge (Figure 11.). They hypothesize that next to practically unreachable tacit knowledge, some tacit knowledge exists that could be perfectly articulated, and other tacit knowledge that could be articulated imperfectly (Ambrosini and Bowman 2001).
High

Deeply ingrained tacit skills

Tacit skills that can be imperfectly articulated

Tacit skills that could be articulated

Explicit skills

Low

Figure 11. Degrees of tacitness (Ambrosini and Bowman 2001)

Figure 12. Combined model of knowledge conversion
In this thesis we choose to expand on this model by combining it with the four basic patterns of creating knowledge as identified by Nonaka (Nonaka 2015):

- From tacit to tacit, through a process of observation and imitation, also called socialization.
- From explicit to explicit, the combination of discrete pieces of explicit knowledge in a new whole.
- From tacit to explicit, the articulation of tacit knowledge.
- From explicit to tacit, the internalization of explicit knowledge (Nonaka 2015) through a “leap into the unconsciousness” (Polanyi 1974) after repeated application.

The combined model in Figure 12 shows the four knowledge conversion processes (i.e. socialization, articulation, combination, internalization), the continuum between explicit and tacit.

**Storytelling**
While all of the four conversion processes are relevant for our project, the process of articulation is of particular interest. Before we have seen that designers use physical artifacts and environments, and their body to articulate tacit knowledge (Vyas et al. 2009). Bhardwaj and Monin (Bhardwaj and Monin 2006) add to this that storytelling is a central mechanism for articulation (Bhardwaj and Monin 2006). Kohtala and Bosqué (Kohtala and Bosqué 2014) underscore the importance of storytelling for learning, establishing reputation and guiding organization in maker communities (Kohtala and Bosqué 2014).

**KEY FINDINGS**

- Ill-structured problem solving involves creativity. Creativity includes a process of exploration that involves the co-evolution of a problem and a solution space through incrementally structuring those spaces.
- Collaboration improves the co-evolution of problem and solution spaces by sharing different perspectives.
- In collaboration teams form a Joint Problem Space that contains a shared understanding of the co-evolving problem–solution pair.
- Participants in a collaborative effort to create a physical artifact make extensive use of physical space and artifacts, and their bodies to develop a JPS.
- Knowledge exists within a continuum between explicit and tacit knowledge.
- Explicit knowledge is formal, systematic and communicates clearly.
- Tacit knowledge is embodied and defies formal analysis and clear communication.
- There are four basic patterns of knowledge creation (i.e. Combination, Internalization, Socialization and Articulation), which are all present in maker projects.
- Storytelling is an important technique used to articulate tacit knowledge.
3. LITERATURE REVIEW

INFRASTRUCTURE

A place for documentation

In early studies for designing mediated collaboration researchers focused on recreating the physical environment to be as true as possible. The reasoning behind this was that collaboration involves physical artifacts and environments, and the media space should not constrain that natural behavior (Gaver 1992). However, it was soon reasoned that the affordances a ‘space’ provides does not stimulate behavior as much as a ‘sense of place’ does. With sense of place is meant “a cultural or communally-held understanding of the appropriateness of styles of behaviour and interaction, which may be organised around spatial features but is, nonetheless, quite separate from them” (Harrison and Dourish 1996).

Placeness is not something you can design in but you can only design for, since it consists of patterns of use (Harrison and Dourish 1996).

Johnson (Johnson 2001) points out that designing a virtual community does not necessarily mean that a community of practice will develop there. In order for such communities to arise the infrastructure should be able to gain the ‘sense of place’ and facilitate the appropriate patterns of use.

In literature on managing tacit knowledge exchange is often mention of creating an environment in which equality, mutual respect, trust, and encouragement exist (Mascitelli 2000; Leonard and Sensiper 1998; Wang, Cosley, andFussell 2010; Johnson 2001). Here encouragement refers to the importance of continuous iteration and the acceptance of failure to create a “culture of innovation” (Mascitelli 2000; Leonard and Sensiper 1998). A lack of mutual respect and equality can inhibit the willingness to share knowledge (Wang, Cosley, and Fussell 2010; Leonard and Sensiper 1998). Holste and Fields (Holste and Fields 2010) identify two types of trust to be crucial for knowledge sharing, affect-based trust and cognition based trust. Affect-based trust is gained by relationships based on mutual care and concern between participants. Cognition-based trust is based on the reliability and competence of co-workers (Holste and Fields 2010). An environment that does not possess these characteristics does not provide the sense of place needed to host communities of practice. Toombs et al. (Toombs, Bardzell, and Bardzell 2015) found that the hackerspace that successfully hosted an active community of makers did have the needed supporting social setting.

In chapter 2.3 we have seen that communities of practices are instrumental in the process of collective invention. These communities form because of a need for exchange of both knowledge and norms. In chapter 2.1 we see that for maker communities the knowledge comprise tool and material sensibility and the norms include adhocist attitudes and engagement with the community. To be able to exchange the knowledge and norms there is a need for physical environments, artifacts, and cognitive tools. Chapter 2.2 describes these physical environments while chapter 2.4 focuses on the knowledge exchange processes. Both mentioned the members of the community of practice being involved in collaborative problem solving. This problem solving procedure for needs a Joint Problem Sphere (JPS) to be upheld between the participants. In the JPS a problem–solution pair is co-evolved in order to solve an ill-structured problem. Maintaining a JPS involves the combination and internalization of explicit and the articulation and socialization of tacit knowledge. Participating in these collaborative problem-solving activities will develop the participant’s identity towards the center of the community of practice. These
activities thus empower the individual, the community, as well as the others in the collaboration. It follows that in order to empower makers and maker communities the communication cost needed to take part in upholding a JPS should be reduced.

Figure 13 shows the JPS as overlap between a maker and a maker community. It is also shown how these spheres expand towards each other because of the activities in the JPS. However, González and Mark (2005) and Kuznetsov (2010) bring to attention that participants in collaboration are often involved in multiple collaborative activities. A better representation of a maker’s practice would look more like Figure 14.

One distinction needs to be made regarding the Open Collaborative Innovation projects introduced by Baldwin and Hippel (2010). Those bring to the attention that within projects with a larger design cost the design needs to be divided into modules, which might need to be completed in parallel to each other. Depending on your definition of collaboration this activity could actually be understood as cooperation. This thesis regards collaboration as an activity where problem-solving is a shared activity and cooperation happens when work is divided and completed in parallel (1995) thus Open Collaborative Innovation could involve cooperation.

To conclude, to create a system that can facilitate knowledge exchange between makers we must answer these questions:

- How can we uphold an environment in which equality, mutual respect, affect-based trust, cognition-based trust, and encouragement exist?
- How can we facilitate the 4 patterns of knowledge exchange?
- How can we support users to maintain multiple Joint Problem Spheres?
Changing habits

One problem that is worth looking at concerns the problematically large cognitive load that is demanded from makers by current communication methods. For instance, video is highly popular as a communication format, with 17% of Kuznetsov’s respondents stating that video material is hugely influential for their projects, yet just under 2% those people uploaded a video more than several times per year(Kuznetsov and Paulos 2010). Kuznetsov et al. also stress that creativity can be captured better by documentation tools that allow makers to reveal their iterative processes(Kuznetsov and Paulos 2010). However, as McKay et al. (McKay et al. 2015) state that it is hard for makers to pause for documentation during their projects, even though they do recognize the advantages of doing so. Hyysalo, Johnson and Juntunen further point out that in many cases sufficient documentation requires a substantial extra effort in maker projects, particularly if the project is not fully digital(Hyysalo, Johnson, and Juntunen, n.d.).

One way to decrease the cognitive load would be to help to provide tools and suggest procedures to stimulate makers to form new habits. As Limayem, Hirt, and Cheung(Limayem, Hirt, and Cheung 2007) describe, habits are commonly understood as “learned sequences of acts that become automatic responses”. Basically, habits allows one to be subsidiary aware(Polanyi 1974) of a sequence of acts, and keep your focus. Limayem et al. identify four antecedents to habit development:

• Frequent repetition of the behavior, the more often behavior is performed the more likely that behavior becomes a habit.
• The extent of satisfaction with the outcomes of the behavior, the more satisfaction can be derived from the behavior the higher the chance that the behavior will become a habit
• Relatively stable contexts, a recurrence of the situational cues and goals of an individual will increase the repetition of the behavior.
• Comprehensiveness of usage, using a system in different ways creates stronger habits with that system compared to using a system with limited ways of use.

So, to successfully facilitate knowledge exchange the question “How to make the appropriate behavior satisfactory, frequent (and fast), and usable in multiple ways?” also needs to be taken into account.

KEY FINDINGS

• How can we uphold an environment in which equality, mutual respect, affect-based trust, cognition-based trust, and encouragement exist?
• How can we facilitate the 4 patterns of knowledge exchange?
• How can we support users to maintain multiple Joint Problem Spheres?
• How to make the appropriate behavior satisfactory, frequent (and fast), and usable in multiple ways?
PART II: RESEARCH FOR DESIGN

4. FIELD RESEARCH
EXPERT INTERVIEWS
CO-DESIGN SESSIONS
EXPERT INTERVIEWS

In this chapter the findings from 14 expert interviews are discussed. This discussion is divided in four parts, each discussing one of the recurring topics that were found in the interviews. The findings per individual interviewee can be found in Appendix A. In this chapter these have been triangulated within each of the topics (italic) and are summarized into key findings (bold). These findings will later inform the design.

Desired Use Cases

These desired use cases describe assumed beneficial practices based on the personal or professional experience of the interviewees. The findings could be arranged in six groups, these are shown on the right. Below is a discussion of these groups.

As is seen in the first group of comments, the interviewees often mentioned concepts such as personal freedom and positioning ones identity. There seems to be a need for “Self-initiated participation in a community of practice aligned with a history of explorative inventors to find ones own way”.

Underlying the comments in the second group lie the assumptions that
• Documentation is stored in suboptimal places for collaboration
• Documentation is time-consuming
• Documentation is not taken into account at the start of a project

In other words: “The belief that their information is able to be a base for effective collaboration could act as an incentive to start documenting. But documentation should be as effortless as possible in order to continue with it”.

The third group of comments take the potential of “lurkers” into account. Lurkers can be understood as people that are not involved in a project, and might not even have appropriate expertise, but add to the iteration of the project’s problem-solution pair by questioning or commenting from a different perspective. The interviewees point out that catering to “bored people” by allowing “casual browsing” will allow people to view projects and “lurk”. In short: “People should be able to enjoy navigating through projects, and be stimulated to leave comments and questions to generate new ideas”.

In the fourth group the interviewees identified the importance of conveying information in such a way that the users have the feeling of quickly and repeatedly achieving progress towards their personal goals. In other words, “Communication should frequently provide satisfying results”.

An important distinction is made in group five that “Participation and roles in groups are dynamic”.

The sixth group reveals that reflection is not a continuous activity, but is done at “key points” in a project, for instance at the end. However, starting to document at such a natural point for reflection is considered to be a strenuous activity. In conclusion “Reflection benefits by being attended to on an interval basis, but documentation on this basis becomes unwieldy.”
GROUPED INTERVIEW FINDINGS

1. This is not documenting for somebody who has authority over you, instead this is by your own choice.
   - If the group identity is more beneficial to add to your individual identity than to other groups, then there can be sharing.
   - Relating your activity with a history of inventions and inventors through patents
   - Formulating your own (or a group’s) goals.

2. Documented material is spread over many platforms and not seen by the right people.
   - Invite people to start early in the process, because they do not start early by themselves, but it is easier if they do.
   - Allow the starting of documentation in the middle of a project
   - Documenting is often done without detail on many platforms (for social and other reasons)
   - Documenting costs too much time as it is now

3. Can the casual browsing activity many people take part in become more meaningful for those who need it to be?
   - Browsing should be enjoyable to entertain “bored” people.

4. Service should support the “right way” to format your information, so it becomes useful for reflection and other peoples understanding
   - Common conversation between makers is often applied to the latest activity
   - Much effort is taken to introduce the (proper) use of tools and materials (tool tips? how-to? key documents?)
   - Entering project space without many log-in steps to start commenting
   - Make small goals to achieve and build self-esteem (Cycle of winning)
   - Keep the low-barrier

5. Group ownership of a project should be possible
   - Group work involves flexible roles and participation
   - Individuals join together to do/design something. But they can form a group.

6. Documentation is currently happening mostly at the end of projects, this is very impractical for several reasons. But it might actually serve reflection, since it is looking back, maybe it is because progress is not documented well enough that this is not optimal.
   - Documentation at key points is “painful” because it requires many separate steps such as collecting materials created, showing their functionality, and compiling it into a decent package for future reference.
Stakeholder Relations

The relations between stakeholders are believed to create an environment that pushes people into the appropriate behavior. The results tended to fit into one of three groups that are shown on the right.

The interviewees do point out that most of the content will be created by a core group of experienced makers. Inside the group there should ideally form a meritocracy between lesser and more experienced makers. Bias between groups on this and other platforms can create unwanted social tension. What seems important in the first group is that all stakeholders share an acceptance of others, either inside or outside of your group. Experienced members should accept that new members will initially not add as much value, but are increasingly able to do so as they progress through interaction. Between groups should be mutual respect and the acceptance that all effort undertaken should be taken serious. In other words “Acceptance is an important prerequisite for interaction”.

In the second group is asked what can be demanded of the community. Can companies take part and benefit from the “free” feedback? Can you pose an urgent question to other members or is figuring out problems your own responsibility? The unifying element here is engagement, if companies or individuals are engaged within a community, they might benefit from it in return depending on their efforts. The more one is engaged, the more one should be able to expect in return. The message here is “Engagement and effort should be rewarded reciprocally”.

Learning is not always creating explicit understanding, shows group number three, for instance, a user might casually visit some projects on making chairs. This might not be referenced explicitly into a project, but it still adds to the knowledge of the visitor. One topic thus revolves around the idea that “Exploration of projects gives indirect clues to visitors. Should this be made visible? And how?”
GROUPED INTERVIEW FINDINGS

1. People that aim to create physical solutions by themselves bring traditional crafts and new technologies together.
   - It is expected that the most of the contributions will be made by a group of core users (as comparable platforms do) and that there will be a mass of people interested in these contributions.
   - More generally, we need to take care of bias between groups related to the platform.

2. Who initiates? “us or them”? Is there room for organic hierarchy, and how do (production) companies present themselves on the platform?
   - There are going to be people that have the (urgent) need for peer support to solve their individual problems.

3. Most likely there will be (bored) people, with or without the urge to make something for themselves but still without any clear direction. They won’t be documenting very well, although they might actually be using what they see.
Values

These are explicitly formulated values that the interviewees believe are required in a successful design.

The first collection of findings shows that documentation and collaboration is regarded useful and important, but for users it is not the most important. The design should obstruct their main goals the least as possible. “Accessibility and ease of use” are regarded central concerns.

Secondly, reflection on done tasks seems a fundamental prerequisite for the progress of the individual development and the collaboration between users. “Transparent organization and clear communication of progress” are to be taken very serious.

The third group reveals the importance of evaluating the roles and backgrounds of others in collaboration. How do we allow people to discover who their interlocutors are, and how do we allow distinguishing between them without involving the rigidity of hierarchy. In other words, how does the system “Reflect Personality”.

“Working together to become better inventors” is what the interviewees unanimously identify as a key value for the users. With work understood as both a means to shape reality for oneself and an iterative, creative learning activity.

Instead of aiming to replace other platforms the interviewees point out in the fifth group that the ability to merge and connect with existing digital ecosystems is a much better way to provide value for the users. “Compatibility” is therefor much needed to be taken into account.

The sixth group points out that performance pressure is accepted to be an effective means of obstructing users to participate on the platform. There was a recurrent train of thought concerning the necessity of limited capability to keep equality. In other words, there should never be a standard of presenting information in such a way that might discourage people. There is a need for “Adequate and Accessible Standards”
GROUPED INTERVIEW FINDINGS

1  •  Accessibility and ease of use
    •  Documenting is nobody’s main task but often demanded. This is where you are providing the needed support.
    •  You give service and empower, you do not take extra effort

2  •  Transparency
    •  Providing a “clean” work environment
    •  Allow finishing tasks (and “versions”)
    •  Show project evolution
    •  Keeping track of your intellectual property

3  •  Flexibility
    •  Open community structure, not based on demanded effort but initiative

4  •  Support self-esteem
    •  Being creative pioneers
    •  Create better ideas/work together
    •  Acquire skills you didn’t have
    •  Redefine failure
    •  Inspiration in a safe environment
    •  What the gains and losses of social behavior and private use are.

5  •  Compatibility
    •  Being a central platform to collect and organize your loose ends on.

6  •  Set consistent low standards
    •  Making documenting a HARD requirement would damage the experience
**Service Elements**

The interviewees mentioned elements the service should have. Again, grouped findings on the right.

Several experts identified the need for **Version Control**, as is usual in digital production projects. Version control gives a user the freedom to go back to a previous state of their project. This allows them to play around with different ideas without running the risk of having to start over from scratch. However, in digital production creating versions is very easy, because projects can be copied without costs. In physical projects this copying is significantly harder and often impossible to do. Unfortunately none of the interviewees had a solution for this problem.

What was also found to be a common request was a **Visual Overview of Progress**. Interviewees were interested in visualizations of a project’s evolution and imagined it could help in getting a quick understanding of a project.

The interviewees were all keen on the ability to **Effortlessly Record a Variety of Media Formats**. There had been experiments in maker spaces with point-and-shoot cameras that were immediately uploading images on a space-owned server. But it was imagined that for the users it would be better if their privately owned phones could use its cameras to store media per project.

There was a distinction made in the fourth group between “Searching Projects” and **Searching in Projects**. Both were regarded as very important.

According to the fifth group, the interviewees imagined that makers would use the content for both receiving help and giving help. For receiving help it was generally accepted that a link or **Reference** should be made to the content, be it in or outside of the platforms own database. For giving help a proper way of leaving **Comments** was deemed necessary to be included. One should additionally be able to “reference in a comment” and “comment on a reference”.

There is a need for creating **Maker Profiles** in order to support various kinds of collaboration. However, do we allow people to create a profile specifically on our platform, or do we import one from another serve such as Facebook or Google. And what are the interactions that are possible between them? Food for thought.

The seventh group expanded on the ease of use that has been mentioned before. It shows it could be reflected in **Intuitive Navigation** through the content.

One assumption made in the eighth group was that **Extending the Existing Physical Spaces** and communities onto the platform would be beneficial.

Not all projects are continued and brought to market by the individual makers. But it would be interesting to be aware how a discontinued project by one maker forms the basis of another project that might be implemented on a bigger scale by another maker. This might form the basis of **Social Production Structures**.
GROUPED INTERVIEW FINDINGS

1. Version control like Github, but adjusted for physical production
   - Editing/Summarizing process in project
   - Marking/saving extensive documentation on set moments

2. From a “need/idea” to a “solution/concept”
   - Transparency on what is going on in a project
   - Visualizing evolution and references
   - Projects are not only one track of action
   - Including time-lined evolution

3. Data transfer/upload/input of text, files, images, links should be effortless
   - Picture are independently taken already
   - Uploading images from box in space did not work

4. Search function should work inside projects as well
   - Overview page (for different criteria)
   - Searchable

5. Asking help based on position in project
   - Integrate with other platforms
   - References
   - Finding, receiving and giving help
   - Project database crawled from makezine, hackaday, thingiverse
   - Connecting progress with other projects

6. Collaboration
   - Following is a good form of interaction but bad terminology
   - Profiles, inside service, imported, or distributed?

7. Long view should be supported
   - Fast scrolling is through content is required
   - Real world analogues
   - Foolproof interface
   - Cycles could act as next commit/step/stage
   - Straightforward and understandable

8. Tracking people’s presence in physical spaces
   - Allowing people to be part of an existing community

9. Stop wasting valuable creations
   - Connection from user generated content to production stage
CO-DESIGN SESSIONS

This chapter discusses the results from 5 co-design sessions. Based on the raw data that can be found in Appendix B five personas are created. Figure 15 shows the position of the personas in the larger maker community of practice.

Persona 1, 3, and 5 are describing members of the community whose main goals are personal projects. Persona 1 has the least experience, Persona 3 has more and Persona 5 has the most, the arrow between them indicates the increase in experience. These persona stories discuss the nature of the personas' personal projects, their collaborative activity and their ideas for the design of a platform for documentation and collaboration.

Persona 2 and 4 share a main interest for educational activities instead of personal projects. They aim to support the movement of other makers towards the center of the community. Persona 2 is facilitating this move closer to the periphery with a more inexperienced audience, whilst Persona 4 is catering to a more skilled group of makers. These personas are treated similar to the others, except that instead of personal projects their educational goals are being discussed.

Figure 15. Position of the personas in the maker community
Persona 1: The Explorer

Personal projects
The explorer feels the inner drive to make things, and wants to improve through learning a variety of skills. During her making activities she loses herself in a train of thought, which causes her to forget about documenting her progress. This disorganized way of working creates difficulties later on. She often lacks the documentation she needs to remind herself about her process, or to explain her activities in portfolios or presentations. The only project she documented really well was one on which she was really proud and that she wanted to show to her peers.

She loves to "lurk" and says she gains a lot of inspiration and contacts because she explores many working environments. By looking at other people work and talking with them she is able to create new projects and find networks and spaces in which she can learn.

The Internet is a huge pool of information from which she retrieves help and directions for tasks she does have the appropriate experience. However, she absolutely needs instructions that are complete, because she does not have the skills yet to fill in any gaps in the process.

Collaborative activity
The explorer enjoys working together with other people on projects and does this often. She has used a large variety of communication media and found that the ones that are most effective are the ones that allow her to connect to the relevant people and are easy to understand. For instance, in a university course involving teamwork her team’s Facebook group would be used extensively to exchange information, but the course’s blog would remain practically unused. This blog is lacking activity because it doesn’t connect her to the people that are relevant to the teamwork and she needs to go through the difficulties of learning how to operate it.

She currently works together with people from different backgrounds in a startup to make a functional product and bring it to market. This involves not only collaboration but also cooperation through the division of tasks by the project manager. The work within this project is mostly asynchronous, with team members working from other countries. The communication in this project is very messy and decentralized. The project members exchanging information through calls, e-mail, text messages, Skype, Trello, Github, Google Drive, Twitter, Facebook and the project’s own website.

Despite having tried so many of them, she feels there are no communication platforms that help her to create an understanding of what her team members’ skills and motivation are. She feels that having this understanding could help communicating with each other in collaborative projects.

She mentions that projects with people from different backgrounds are hard for her as a beginning maker. In these teams she has no access to the peer and expert feedback that she really needs. At the moment she also does not know where to find that feedback.

Design
Her ideal communication platform would help her to understand skills and motivations of people so she could find experts, peers and other people to discuss her work with. She would like to continue her “lurking” online and see other peoples work and ask questions about it. She does understand the importance of documentation for this but does not know how a communication platform could help her pause her train of thought without stopping it.
Persona 2: The Shepherd

Educational goals
The shepherd’s goal is to introduce making to new audiences. He takes on the role of a teacher and wants to communicate lessons through projects. A project could for instance revolve around the importance of iteration of the value of theory for making. He develops these projects with great care and takes into account that his audience has little to no experience with making.

Collaborative activity
He is part of a community of shepherds that has a long history and has formed a union. The union has helped information exchange between shepherds for decennia, and has its own publication and online communication platforms. The union is divided in several informal groups based on expertise. Shepherds’ projects are usually connected to their specialization, even though they feel the need of introducing many different skills to the audiences. This is why they within the union projects are actively shared across disciplines.

Design
The shepherd identifies two important design directions for audiences that are new to making, these are:

• Social pressure is bad, with this is meant that new makers are insecure about their projects and are easy to discourage. For instance, if they feel the quality of their creation is too low they will not want to share it for the fear of being bullied. The shepherd did find that the audience feels comforted when they are able to exhibit their work anonymously. The shepherd thinks a successful communication platform should have an environment in which cluelessness is cherished.

• Basic and unified communication. According to the shepherd there should be easier ways to document and share information. What he thinks is of key importance is the development of rough standards that could guide users to document quickly and thoroughly throughout their process.
Persona 3: The Entrepreneur

Personal projects
The entrepreneur is a maker with sufficient skills to initiate his own projects and is looking for ways to develop his business. The projects of entrepreneurs are an accurate reflection of their skillset and experience. Entrepreneurs have an abundance of nearly finished projects that are lying around waiting for investment.

Entrepreneurs are continually on the prowl for resources. These resources include:
• Physical space, tools and materials
• Stimulating social environments
• Funding

Collaborative activity
Entrepreneurs in the maker community are socially active and often act as a mentor for other makers. These are not purely altruistic activities; they are developing their skills by sharing their knowledge and projects. It also provides them with a platform to demonstrate their expertise and gain prestige.

Design
Entrepreneurs need to be visible and prove their expertise in order to stand out. This is important because those who stand out increase their opportunity to get resources. They need to be involved in several social environments in order to function effectively, so any communication platform should support that activity.

Entrepreneurs develop their profile by sharing their ideas to gain prestige. This demands that their contribution should be able to be attributed to them; otherwise they will not share anything.
Persona 4: The Supervisor

Educational goals
The supervisor is providing support and guidance in maker spaces. His function is to share his expertise with tools, materials, and making processes with makers that are able to create their own projects.

Collaborative activity
For this the supervisors tested and developed various online platforms for documenting a fabrication process. On most of these platforms progress could be documented using step-wise textual explanation and uploaded image material. It was also possible to save files, and manually store tool settings in a form. Documentation on this platform was meant to be compulsory whenever there was use of the maker space. However, using the tool was found to be too difficult and was discontinued.

Design
The supervisor has a variety of ideas for a new platform that can be grouped in five topics:

1. Process
There are different types of processes; some makers are more focused on doing, while others are mainly thinkers. The platform should be useful for both of these types.

The supervisors experience with guiding projects shows him that makers need to be asked for updates on their progress. Otherwise they would not start to articulate their knowledge. Any design should take into account that this direct stimulation could be necessary.
For this he proposes a reward system that would award documenting and make it more fun to share.

2. Documentation
The supervisor had previously arranged for a camera that would upload pictures straight to a central database. However, this was not easy enough and final documentation was still very fragmented.
Makers were already able to upload their files to the database, and the platform was integrated with Github. According to the supervisor users should be free to use a wide variety of media formats. He adds that file previews can make documentation more understandable.

3. Community
The supervisor had troubles with making networks last. A new platform should be able to preserve and activate networks created at social events or based on shared interests.
One idea was to make the app embeddable as an element on other platforms.

4. Participation
His experience with the former platform had taught him the valuable lesson that there should be some forms of legal policy to set norms.
Another major improvements could be achieved by ease of use, fast loading time and digestible content.

5. Fabrication
The supervisor was convinced that the main goals of any documentation platform were the acquiring of skills and finding experts. He mentioned there should be a way of creating and finding key documents.
Persona 5: The Cornerstone

Personal projects
The cornerstone is capable of independently initiating and completing projects and learning processes. He is involved in various specialized online platforms for sharing and retrieving information, and enjoys the detective work that goes into component “hunting”. He trusts his skills and has clearly formulated his own specialization and interests. This confidence is what he thinks is the central thing that each individual develops, and he believes within the maker community “You do you”.

Collaborative activity
Next to these well-developed individual processes the cornerstone fulfills an important, sometimes crucial, role in the maker community. By understanding the role the community has played in his development it is only natural for him to volunteer his time and become engaged with or initiate community activities.

Design
The cornerstone recognizes that not many makers are actively documenting and wants to improve this. Like the supervisor he has acquired a camera that can automatically upload pictures to a central database. According to him the added visibility and transparency of the maker community will eventually strengthen it and allow it to expand.

The cornerstones within maker communities are very likely to organically develop digital ecosystems capable of all the main needs for the community. One particularly treasured and resilient element of the ecosystem is the IRC feed. This continuously active conversation is where the community is able to synthesize its knowledge in a “collective memory” where norms are exchanged and help can be found. However, one major drawback of this IRC feed is its fleeting characteristic and the continuous loss of information.
PART II: RESEARCH FOR DESIGN

5. DESIGN DIRECTIONS
1. Developing an identity

In the literature research it was found that there exist degrees of “maker-ness” through which makers gradually progress. This degree of maker-ness represents their identity and is shaped by their tool and material sensibility and adhocist attitude. A tool and material sensibility empowers makers to envision and pursue new DIY activities. It is achieved by becoming deeply familiar with different tools and materials. The adhocist attitude empowers makers to rely on their making practices to iterate solutions. It was also discovered that maker communities facilitate the identity formation processes of makers and contributing to DIY communities is done to establish ones individuality.

The field research stresses the importance of “Maker Profiles”, for instance the Cornerstone states that “you do you” in the community. The Explorer wants to study these maker profiles of people connected to her to create an understanding of their skills and motivations. She also wants to use this to find experts, peers and others to discuss her work with. The entrepreneurs attempt to develop their profiles by sharing their ideas to reflect their personal capacities and gain prestige. They believe their projects are an accurate reflection of their goals, skillset and experience. Referencing each other whenever relevant is thus desired behavior. Supervisors state that main goals of any documentation platform are the acquiring of skills and finding experts. They share the thought that makers can develop their skills through sharing their knowledge and projects.

2. Ill-structured problems need collaboration

The research identified that maker communities are communities of practice brought together by a need to solve ill-structured problems. Solving ill-structured problems was shown to involve creativity. Creativity was understood as a process of exploration that involves the co-evolution of a problem and a solution space through the incremental structuring of those spaces.

Teams form a Joint Problem Space that contains a shared understanding of the co-evolving problem-solution pair while collaborating. The Explorer shows the importance of this JPS for collaborative media by connecting it to the lacking activity on a school blog. She mentions that happened because it didn’t allow her to share with people that she felt were able to connect to the team’s activity. The Cornerstones aided the organic development of digital ecosystems to fit their local needs. This ecosystem relied heavily on the sharing of different perspectives.

3. Partaking in a tradition of invention

The DIY culture is thus a culture consisting of members that collaboratively explore, experiment and understand. DIY-like activities have been recognized in episodes of collective invention. Such episodes thrive on sharing of information and shape technologies during the early stages of development. This form of collective invention and user innovation has significantly influenced commercial product and process development.
The feedback from the community shows these findings are no secret. It is commonly known that makers work together to improve inventions that turn out to be very influential. Finding your own way in a community of practice aligned with a history of explorative inventors is meaningful for makers. The shepherd proudly mentions that the community of shepherds has a long history and has even formed a union.

4. Shaping social production structures

Some pointed out that the act of making could be understood as social criticism within the current economical context. However, there is proven to be a positive influence of both Single User Innovation and Open Collaborative Innovation on the traditional innovation structures. Especially Open Collaborative Innovation projects carry a lot of potential. Unfortunately current communication platforms are not optimal for facilitating these projects. This supports the idea that UX design can provide meaningful solutions in this context.

The Supervisor addresses the urgency of making collaborative networks more durable and last longer. The Cornerstone acknowledges this, and is actively attempting to improve the visibility and transparency of a maker community to strengthen and expand it.

5. Community based peer learning

Maker spaces form a base for rethinking innovation, research and development. They facilitate a social environment that enables communities of makers to progress as makers. The Cornerstone is a core member of a community and thinks it is only natural to be engaged with its activities. These activities often involve knowledge sharing. This is common in the maker culture; the Shepherd states that for instance their union is actively sharing projects across disciplines. This peer learning involves the formation of mentors-apprentice relationships. The interviewees point out that these formations are fleeting and are highly dynamic.

Not only skills are shared in these relationships. In maker communities mentors reflect the group prototypes and set and communicate the norms. Norms are fluid and context dependent representations used to position a group in relation to others. They are changed and maintained through communication and internalized by group members through group prototypes. It is therefor no wonder that a high-level mentor such as the Supervisor mentions the necessity for developing legal policies to set norms. Another established maker, the Cornerstone, points out that their hackerspace’s continuously active conversation on IRC forms a “collective memory” which helps exchanging norms.

Since aspiring makers such as the Entrepreneur are constantly the prowl for expert knowledge and resources the Supervisor stresses the importance of creating and finding key documents. The interviewees agree that a communication platform should be able to extend these existing physical practices.
6. Learning across different communities

Ill-structured problems and collaboration cause makers to be involved in multiple communities. The explorer goes to great lengths to locate and exchange a variety of information and expertise that she needs from peers and experts. The Entrepreneurs explicitly state they want to be visible and involved in several social environments. A challenge arises concerning the question how to enable users to reach and engage in Joint Problem Spheres. According to the interview findings the design should allow intuitive navigation between and within projects.

7. Compatibility on both ends

A previous system attempting to aid maker documentation offered integration with Github. But both the Explorer and the Supervisor mentioned that makers generally use a large variety of communication media to find help and present their work. The Supervisor would like it if the app could be embeddable so that his apprentices could share their project’s progress on the maker spaces’ own website. The design should thus be compatible with material coming in from other media, but also allow makers to present their documentation on other media.

8. Easy documentation

One key finding that was found right at the start of the thesis was that users of physical DIY spaces perceive the activity of documentation as tedious and not fun. The Supervisor, that supervises such a space, is familiar with this tendency because he often needs to ask makers explicitly for updates on their progress. A huge chunk of the field research highlighted that the service should be fun and easy to use. Documentation should be as effortless as possible in order to continue with it.

The most experienced personas, the Supervisor and the Cornerstone, had actually both bought a camera with an “eye-fi”-card that can upload pictures straight to a central database. They both underlined the importance of recording a variety of media formats.

9. Dare to share

It was discovered that positive feedback on creativity is important for DIY contributors. And contrastingly, that the possibility of receiving negative reactions deters people from sharing their materials. The Explorer had only thoroughly documented one project because she felt really proud of it. The Shepherd, who often deals with makers on the level of the explorer, is fully aware that of the importance of confidence and the detrimental effects of social pressure.

The field research indicates that acceptance is an important prerequisite for interaction. To found the belief that any effort is worth sharing the Supervisor proposes a reward system that would award documenting. The interviewees would also like to see engagement being rewarded reciprocally.
10. Care and communication

The literature review directs the attention to the questions dealing with how the service can uphold a social environment based on respect and trust. The explorer likes to “lurk”, which she describes as being silently present near people working, to see what they are doing. She finds that in maker spaces she is welcome to do this. But she would appreciate it if she could leave a trace indicating that she had been present near the activity so that people could connect her to it later on. The benefits of leaving messages and traces is stronger accentuated by the interviewees. They want people to enjoy navigating through projects and leaving comments and questions to generate new ideas. The literature review adds to this by putting the question how to make appropriate behavior satisfactory, frequent, and usable in multiple ways to the forefront.

11. Troubles with tacit-ness

Documenting a DIY project is difficult because the creation of physical artifacts involves tacit knowledge. The literature showed that knowledge exists within a continuum between explicit and tacit knowledge. While explicit knowledge is formal, systematic and communicates clearly, tacit knowledge does not. Tacit knowledge is embodied and therefor defies formal analysis and clear communication. Knowledge creation happens when knowledge gets exchanged. There are four basic patterns of knowledge creation (i.e. Combination, Internalization, Socialization and Articulation), which are all present in maker projects. Storytelling is an important technique used to articulate tacit knowledge. It is also shown that participants in collaborative efforts to create physical artifacts make extensive use of physical space, artifacts, and their bodies to articulate knowledge.

The Explorer addresses the problem that she does not know how to pause for documenting her work without breaking her train of thought. Especially articulation is a very demanding way of sharing knowledge, and is significantly disturbing the process of working on a project. However, the use of video might help out with this problem.

12. Comprehensibility

Lastly, the field research reveals the need for transparent organization and clear communication of progress. The Supervisor breaks a lance for file previews, and the Explorer wants her instructions to be complete. More stringently, both the educators, the Shepherd and the Supervisor, directed the attention to the need of adequate and accessible standards. According to the Shepherd the communication demands basic and unified structures to guarantee quality. The Supervisor attributed to this that it would additionally benefit the ‘digestibility’ of the content.

It was also hypothesized that although documentation should be done continuously, reflection might benefit from being attended to on an interval basis. These reflective moments could be the base for creating what in digital production is referred to as version control. The divisions of stages within a project could further increase transparency by being visualized and aid cooperation within teams.
In short, the design should enable makers to:

1. Present themselves with profiles reflecting their identity and personal development through a collection of projects and references. (Profile)

2. Participate in Joint Problem Spaces for structuring problem and solution spaces with different perspectives. (Joint Problem Spaces)

3. Connect to a history of influential inventors whilst collaboratively exploring and experimenting. (History)

4. Have the ability to make open collaborative projects and networks feasible. (Open collaboration)

5. Exchange skills and norms through mentor-apprentice relationships and creating key documents. (Mentor-apprentice)

6. Intuitively navigate between and within communities and projects. (Navigation)

7. Collect information from and present activity on other platforms. (Compatibility)

8. Enjoyable and effortless communication using a variety of media formats. (Multi-media)

9. Establish confidence through documenting and sharing activities. (Confidence)

10. Maintain appropriate habits that generate mutual respect and trust. (Culture)

11. Document the processes of combining, internalizing, socializing and articulating knowledge while sustaining their main task. (Knowledge creation)

12. Keep documentation transparent through basic and unified communication and subsections. (Comprehensibility)
PART III: RESEARCH THROUGH DESIGN
6. PROTOTYPE #1
DESIGN
PROTOTYPE EVALUATION
DESIGN

This chapter will discuss the design decisions made during the construction of the first prototype. The prototype is called Pelori, which is derived from the name of a type of compass called “pelorus”. Pelori is a working mobile application running on Android and iOS. It is specifically chosen to make this prototype interactive. It will act as a vehicle for gathering data needed to validate the assumptions made in Chapter 5. This way the understanding of what is required of the UX of a system able to facilitate knowledge transfer among makers can deepen. To ease the evaluation of the application it is chosen to develop the prototype alongside the 12 identified design directions.

At this stage Pelori allows a user to explore a maker profile in the application. A maker profile consists of a picture and name of a maker, and a list of their documented projects. These project documents are referred to as “Logs”, like a logbook. The prototype allows users to create new logs with the profile’s functions, and find logs of other people through a search function. A log menu helps both visitors and owners to review activity in the log. The owner of a log can adjust the log settings in this menu as well.

After entering a log an owner can add entries. Entries can be either text or images. A toolbar on the bottom of a owned logs is intended to make inputting entries as effortless as possible. Each entry has its own menu that can be used to view activity or to leave comments. Visitors are always able to leave comments; this should stimulate interaction and learning processes. Entries can also be referenced, by tapping a button in the entry menu an entry can be copied into another log. This copied entry is presented in the other log as a link to its original log. Lastly, logs can also be shared across platforms through the use of “sharing links”.

A tool for creating structure is provided. This tool allows users to identify stages in creative processes. The steps are “Planning”, “Activity”, and “Summary”. The idea is to use these steps as navigational aids. For this reason they have each been given their own color. The colors are based on marine maps; inspiration for this was drawn from the pelorus.

The rest of this chapter will proceed with discussing each of the elements of the prototype in more detail. Since the elements are created along the 12 design directions these will be used to structure the chapter. Image material shows how the elements developed from their sketches to implementation in the actual prototype. Additionally, attention will be paid to some concepts that have not been implemented but are worth mentioning or being discussed.
1. Profile
A profile is meant to reflect individuality; it should display motivation and skills through a development process. The profile owner’s collection of projects plays a central role. The profile develops when this collection expands.

Implemented
Profile
The profile in the prototype has been close to existing design patterns, an avatar image placed above a user name, both on top of a cover image (as in Figure 16). The cover image has a black gradient towards the bottom so that even light images contrast with the white bold text. The cover image was intended to show the context the maker sees himself or herself in.

Tapping the username will open the profile settings (second to right picture in Figure 16). These are basically only the username and the e-mail address. At this stage the password verification is still unclear and is thus not included.

Log list
The project list is meant to showcase the maker’s skills and progress to others. But for the maker it is a logbook of previous activity, which is why personal projects are referred to as “my logs”. Owning a log is initially done individually, but multiple users can be invited to collaboratively own a log.

In the prototype is an unlucky placement of the “featured log” on the profile screen. These logs are not supposed to be there, but ended up in that place because of the deadline for the Maker Faire.
Log menu

The log menu allows users to get an overview of the activity within a log. In this menu, presented in Figure 17, are four information channels visible for all users after tapping a menu icon on a listed log:

- Latest edits
- Collected References
- Latest comments
- A list of the included steps

There is a fifth option for managing the log settings available for the log's owners, allowing them to:

- Toggle the log visibility
- Invite new members to the log
- Copy a link for sharing the log

Concepts

- Black and white, possibly oval avatar images, to relate users to great inventors during the industrial revolution. Have not been implemented, they didn’t connect with the rest of the interface design.
- Jack the Pelorus as default avatar image. Jack the Pelorus was a famous dolphin that used to navigate ships through dangerous waters in New Zealand in the early 1900s. There is another Pelorus Jack, who was a pug named after the dolphin and was held on a warship. Portraits of these animals could be used as fun initial avatar images. Has not been implemented because of lack of time but is planned for a later version.
- Geolocation. Could be used to bring makers closer together, and stimulate connections with local communities. Has not been implemented but might return in a later test.
- Stupid easy sign up and log in. The target group has an aversion for putting effort for learning and setting up new virtual co-working spaces.
2. Joint Problem Spaces

A log is the base for sharing a JPS; it communicates the co-evolving problem-solution pair. Logs should allow users to:

1. Introduce and accept knowledge. Which is why users are able to create new entries in the log, and these entries can be discussed with comments. To improve the co-evolution with contributions from different perspectives logs remain visible and open for commenting to everyone.

2. Monitor on-going activity for evidence of divergences in meaning. The knowledge in the log should remain transparent for all the users.

3. Repair divergences that impede progress of the collaboration. Users should be able to reflect on and plan directions within a log.

Implemented

Entries (see figure 18)

Logs consist of entries. Entries are uploaded “blocks” that contain content i.e. text or images. Each entry has a timestamp and stacks in chronological order. In the prototype the latest entry is on the bottom of the log, that way it is easier for the reader to see a project develop. This particular order is inspired by step-by-step tutorials. Only a log’s owner can add entries to a log. Screenplays have inspired early versions of the entries. These documents share the intention of revealing situated communication. Screenplays choose to deal with contextual information by displaying it centered between the dialogues.
Entry menu

Each entry has its dedicated menu (visible in figure 18 and 19) where comments and other information can be found. This menu has iterated many times since its functionality has been changing as more research data was gathered. In the prototype the menu is centered below the entry. The latest iteration has working notification badges. Although there has been a lot of experimentation in order to find the right way to create an interface it is still far from perfect. The menus make the logs look really messy and draw attention from the main story.

Comments on entries

In the application everybody can comment inside other people's logs, an example is shown in figure 19. What is new compared to other platforms is that comments are connected to individual entries. This ensures that users can comment in a log at any stage and that conversation is contextualized and connected. In other platforms commenting is usually done at the end of an article and does not have these qualities. One drawback is that the collections of comments disturb the reading flow of the log.
3. History

There is need for a group identity. Considering the history of DIY invention, the application could stimulate users to feel like they are part of a special group of inventing pioneers that are exploring unknown possibilities. The community could be presented as an equivalent of the famous “Explorers club”. The application would then function as an instrument for navigating the exploration. Because maker exploration relies heavily on relating and referencing to foreign entities the navigational instrument that is most fitting to be used as allegorization is the pelorus. Implemented Colors

The colors are inspired by the exploration theme. They are picked based on the colors present on sea-faring maps, this process is shown in figure 20. On these maps land is usually shown as a sandy colored surface, water is mainly white, but shallower water is blue and even shallower depths are indicated with an overlap between the sand and blue. There is often a bright purple or pink use of lines to indicate areas and paths. Color swatches were derived from several of these maps. These were triangulated and converged into a final set of four colors.
The top left picture in Figure 21 shows the pelorus from which dial the icon is derived. The early iterations were in black and white to get a balanced composition. One important element in the icon is the sphere in the middle that is reificated by the arrows and aiding lines using a gestalt principle. Reification is a technique that can be used to articulate tacit knowledge i.e. storytelling, and is therefore central to the service. The little arrows moving towards the center emphasize the integration of references.

The dial was later made white and put on a colored background showing the sandy shore in the bottom right corner and a progression into the water towards the top right. The “P” extends and is moving out over the sand (stability) towards the sea (endless possibilities) and leaves the frame (out of the box). The bright lines depicting routes on the maps inspired this progression. The icon wants to invite people to stand out, explore and progress along their own path.

The italic font used for the name of the app is derived from the seafaring maps. The same goes for the font of the slogan. The name is in the bright pink to capture attention, just as the color does on the maps.
4. Open collaboration

**Implemented**

**Featured Logs**

In Pelori logs are by default open for viewing and commenting. Open collaboration is thus theoretically possible. Larger and more ambitious projects need to be brought to attention in order to stimulate people to participate. For this we have mocked up “featured logs” (see Figure 22) which are selected logs brought to the user’s attention. On what basis this content is going to be recommended is in this stage still unknown.

**Concepts**

Two elements that are intended to enable open collaboration, the inviting of new users and the featured logs have been mocked up. The idea of being able to follow users and projects was not finalized nor implemented in the prototype.
5. Mentor-apprentice

Implemented

References

A maker's effort is not limited to individual projects; there are also social efforts in which mentor-apprentice relationships are formed. To make these social efforts visible the profiles are linked to entries and comments in logs. Entries from other logs can be referenced in one's own to make the peer learning transparent. While mentioning names on contributions is a common practice, referencing used knowledge is not. But documenting the harvesting of knowledge materials could stimulate the creation of networks, collaborative iteration, identity building and easy navigation.

One design challenge arose around the icon that could communicate this referencing functionality. It was decided to go with an arrow derived from the face of a pelorus. But as can be seen in the prototype shown in Figure 23 this functionality is still far from being clear.

Concepts

One idea that has been discontinued was the inclusion of “Badges”. These badges could show a maker's achievements and status within a community. This is common practice in several forums and was also mentioned in a co-design session. However, it would create inequality between the users, which has been identified as an obstacle for sharing and was therefore not implemented.
6. Navigation

Makers should also be able to explore activities and knowledge related to certain topics. This way it becomes easier to discover in which field of expertise you might need to develop. Makers should be able to look up logs per topic.

**Implemented**

Search

The search function is created along standard design patterns (Figure 24). A magnification glass is used as a button that navigates to a search page. Searching is done through inputting text in a search bar on the search page. On the results page logs are listed in a similar fashion as on a profile page.

**Concepts**

- Featured feeds, which are now mocked up in the profile page but should be shown in the search page before a search is conducted.
- Search within a log as a way of fast navigation within longer logs.
- Filtering of content within a log
7. Compatibility

*Implemented*

The design should communicate the concept that the application provides a convenient way and place to store stuff for the time being. It should be easy to import copied links and export documentation. The log that is being kept is a repository of information that will later be edited.

Looking into logs can be very enlightening for other makers. There is a sharing link for each log in the prototype that can be copied to other platforms (see Figure 25). This way of sharing could be improved by making the application embeddable.

*Concepts*

One feature that hasn’t been implemented in the prototype was the dedicated browser, the sketch is visible on the left in Figure 25. To allow users to conveniently link to other websites the app was planned to have a “search on web” function. This function would open a browser that included a referencing button. It was not implemented because of its complexity and it was far from being an elegant solution.
8. Multi-media

Implemented
Entry Creation Toolbar
Within the log the focus lies on the creation of various types of content. The possibility of adding documentation should always feel “at hand”. More specifically, selecting the desired format should not take extra time from the user. For this goal a toolbar (see Figure 26) is integrated in an owned log. In the prototype the toolbar is functional and can be used to start writing new entries, and take pictures with the camera or the internal memory. A simple tap on the icon will launch your preferred input method. On the toolbar is a mocked up placeholder for audio input. On the far right on the toolbar is a button for inputting steps.

Clean Design
The negative connotation of documentation relates to a messy selection of fragments such as notes, files, pictures and sketches that have stains and torn edges and need time and effort to be ordered. The service should prevent the content to relate to this idea of documentation. Instead, going through the content should reveal a documented story and content should appear as if it was already logically ordered.
Concept
The early sketch in Figure 27 tried to show an ideal layout. An overtly simple interface could accommodate easy reading and increase learnability. The design has since dealt with the adding of many features, and the prototype does not remotely share the organized appearance as this sketch. However, it remains one of the core goals and will be worked towards in later versions.

9. Confidence
Concept
Anonymity
Allowing users to be anonymous could, according to the research, take out the sting of social pressure and allow users to gain experience with sharing materials. After gaining enough confidence the user could change their status to public and reveal their profile. In the design translated to a “ghost” profile (see Figure 28). This profile would act as an anonymous mode in which the user could choose to go and be active in the app under an alter ego. However, this holding back of one’s own identity was deemed detrimental for building trust and the feature was regarded undesirable.

Likes
Another idea that has been played around with was the “liking” of logs and entries (see Figure 28). The thought behind it sprouted from the finding that positive feedback was stimulating users. Likes could help to quickly give positive feedback. Although this way of liking is a very common way of showing affection for online content it also creates inequality. Not generating likes makes the status of not liked content unclear; it could be either not judged or judged badly. Both of these scenarios are undesirable and could potentially lower the confidence of the user. Likes were therefore deemed unfit as a method for receiving positive feedback.
10. Culture

Concept
Creating an appropriate environment based on trust, equality and mutual respect has been involved in evaluating the design of elements, and even conflicted with some such as the badges for mentors, liking and anonymity. However, in this version of the app the question what could uphold the desired norms in the community has not been answered.

11. Knowledge creation

Implemented
A picture is worth a thousand words. This is ever so relevant for communicating tacit knowledge. Tacit knowledge is usually transferred through imitating behavior after seeing it in context. In the prototype the use of photography was therefor put into a central position.

12. Comprehensibility

Implemented
DIY activities are iterative processes, which means they go through subsequent cycles. The prototype enables users to create a light structure in their documentation through annotating their entries as part of one of three “steps” of an iterative cycle (see Figure 29).

Evolution of log steps
The first version had only two steps, a “plan” and a “do”. The plan would contain reflection and goals and the “do” would show the documentation. A later version changed the names and included two more steps, one for collecting references, and another for creating a summary and reflection. Because references were re-designed as a special entry only three steps remained. Since stability is increasingly found in this process the first stage, of planning, got the blue color, symbolizing the fluidity of ideas. The activity stage has the color of the shallow water and the summary stage the sandy beach.
Concept

Navigating through steps

These steps can function as navigational aids within logs (see Figure 30). Based on the layout of a logbook a list of steps was designed to give an overview of the content and navigate through the iterative cycles. This list was mocked up in the prototype.
PROTOTYPE EVALUATION

Please refer to Appendix D for the shared documentation of the research activities and feedback on the Maker Faire UK and Media Lab Demo Day.

The responses to the prototype were promising. Many evaluators said they would like to use the app, both individually and for larger groups, and urged us to finish it quickly so they could. However, for this thesis this does not clearly indicate success, intending to use something is not the same as being able to actually use it. More meaningful findings at this stage were the improvements that people came up with after becoming familiar with the prototype. This feedback identified seven areas of improvement.

Notifications
How does the application communicate with you when you are not directly using it? Which notifications does it give you? For the users notifications are important, but become considered as inconvenient when implemented in ways that do not fit their use.

Content management
The steps were not understood very well. Instead, people expressed a need for organizing their content through sub-logs so that they could multitask. Also the moving and removal of logs and entries had not been implemented yet.

Visual documentation and annotation
The documentation with and organization of visual media was regarded as extremely useful. But respondents saw room for improvements, such as annotating pictures and including video.

Culture of failing
People wanted to become part of a culture in which failure is being accepted as a good thing that is necessary for progress. But the app itself was not communicating this directly to them.

Exporting and compatibility
To be more compatible with their needs the respondents urged the need for integration with a desktop or web-based application to store links and exporting content to .pdf documents.

Physical limitations
Tests with and experience from respondents indicated that during making activities the physical handling of a phone is often difficult because of damaging materials and safety measures like gloves and glasses. Especially text input through the use of a keyboard was deemed impossible in many circumstances. Many mentioned that speech input would be able to make a big difference here.

Performance issues
The functionality of the prototype was not optimized, and several performance issues were discovered during testing. The most important was the slow loading of large logs.
PART III: RESEARCH THROUGH DESIGN

7. PROTOTYPE #2
DESIGN
USABILITY TESTING
The prototype has been iterated based on the findings mentioned in chapter 6. For a comprehensive list of improvements made to the prototype one can visit Appendix E. All changes have been made during an intensive 7-day development process. Time was limited so not all designed elements have been implemented. Regardless, the application has drastically improved after this process. The current design will be discussed in this chapter in a similar fashion as chapter 6. As before, the design is aligned with the 12 design directions and both implemented changes and relevant concepts (in italics) are discussed. However, the supporting image material takes prototype #1 as point of departure instead of the sketches as was done in chapter 6.

The core structure of the prototype is still very similar to its predecessor, and the application is therefore still referred to as Pelori. There has not been enough time to create a desktop-based version, so it still remains a prototype for mobile devices.

The application has a similar profile page, but the elements have been redesigned. The profile image is larger, as are list elements of the logs. The log menu has found a new place inside the logs instead of being on the list element. Another new feature is the possibility to create your own profile in the application by signing up with your Facebook account credentials.

Logs are still consisting of entries that can be commented upon by everyone. However, the entry menu and commenting functionality have been redesigned. Also the toolbar for entry input has been given more functionality and tapping an icon now opens menus to host these new functions.

Some radical changes have been made in this second prototype. Referencing has been replaced by sharing links to make those more ubiquitous. This was done to improve the compatibility and the ease of use. Additionally, the steps have been removed since they were not considered helpful. Instead it is now possible to organize a log and divide work through sub-level logs.

There has been made a start with collaborative functionality. Logs can now be made editable by anyone. This was done to explore open collaborative environments. Next to this a variety of new functions are now mentioned in the prototype, including the tagging of pictures, activity feeds, sending and managing notifications, and following users and logs.
Implemented
Profile pictures
To improve the connection with the people behind the profiles the design of the profile pictures was changed, as is visible in Figure 31. This new design is supposed to invite users to create a portrait of both themselves and their environment in one image. For this reason the image is taking up an unusual large portion of the screen. A planned improvement is to make these pictures moving in a later stage. A future version would also partially hide the top and bottom of the image by default.

Log list
The listed logs in the second prototype are showing more information than previous versions. A short glance is supposed to give more clarity on what is in a log.

As was intended, featured logs are now removed from the profile list and are placed on the search page instead.

Concept
Activity feeds
All profiles are now including a mock up of an activity feed in which application wide activity of the user will become documented. Reviewing past activities is beneficial for both profile visitors and users. When implemented the activity feed should also be able to show activity from followed profiles and logs.
Log menu

The log menu (Figure 32) has moved from being under a button on the listed profiles to a more prominent position on the log’s bottom menu. One new feature of this menu is that it allows users to remove their logs.
2. Joint problem spaces

Entries
To fit the order of other social media such as Facebook and Instagram, the order of the entries in the log has been vertically mirrored. The most current entry is now shown on the top position.

Request attention
A JPS should be able to be brought under attention. Tapping the “!” icon in an entry menu will send a notification to followers of the log and related profiles. Current ideas include the notification having a standardized format, including the name of the sender, log title and a simple “!” . This format allows for a flexible use of the notifications. Notifications can be stopped through the entry’s menu.

Entry menu
The entry menu (Figure 33) has been moved from in between entries to the upper right corner. Tapping a “V” shaped icon opens a drop down menu. This allowed including extended functionality and removed clutter from the logs at the same time.
Comments on entries

Commenting has been redesigned and partially implemented, changes are shown in Figure 34. The comment icon has been moved to the lower right corner of an entry. Tapping the icon currently opens a comment area underneath the entry, but should in a future version open in its own dedicated screen. This because a comment section has been identified as a JPS on itself. Comment functionality will also be extended to the full multi-media toolkit that is already available for entries.
3. History

**Implemented**
Search Icon
The exploration theme has been further implemented by changing the search icon into a globe (Figure 35). Because the overall design of the app changed and now relies less on the previously selected colors they have been imbued in the little world map. It is intended to relate to a browsing experience.

**Concept**

**The flag**
A planned feature related to the history is to find an equivalent of the flag that members of the Explorer’s Club bring to and proudly show on special expeditions.
Perhaps links shared from Pelori could include a Pelori icon as a “flag”. 

Figure 35. Search icon
4. Open collaboration

**Implemented**

Sub-level logs
To support the division of tasks, allow users to cooperate, and make modular things, logs can now be created inside other logs. One example is shown in Figure 36.

Extending ownership
To further stimulate open collaboration, ownership of a log can be classified as "Open collaboration" (Figure 36). This means any user can add to this log as if it were their own. Open collaborative projects are featured by default on the search page.

**Concept**

Pay for privacy
This prototype (Figure 36) assumes that private documentation is needed only when something is being developed for commercial goals. Hiding your content from other users is made possible, but only as a paid option.
5. Mentor-apprentice

**Implemented**

Copying links

Instead of introducing the concept of references, the more commonly known copying of links is used to address the use of materials. The entry menu, profile menu and log menu now all include a link copying function (Figure 37). This way referencing materials from inside and outside of the application is done in a similar fashion. However, including the functionality in menus might not be enough to build a habit of referencing. This has to be addressed in a future version.

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**Concept**

**Following**

Although not implemented, the need of the ability to follow activity in logs and profiles is regarded as essential for mentor-apprentice relationships. When specifically interested in a log or a user, one can follow activity. Additionally, a user can choose to receive notifications for the followed object.
6. Navigation

Concept

Checkboxes for filtering

These were not implemented, but to ease navigation through the content heavy logs the design could rely on filters. The improved search page has one filter for discerning open collaborative projects from others (Figure 38).

Key documents

Key documents could be identified by toggling the attention “!” icon in an entry menu, or by making and naming a separate log/sub-level log. Although relying on this variety of organizational activity from users seems far from an ideal workflow.

7. Compatibility

Concept

Because of their complexity the solution related to compatibility have not been implemented in the second prototype.

Desktop or web-based version

A desktop or web-based version would be useful for adding larger amounts of text, code and links. The integration between platforms would be beneficial for most, or all, types of users.

Store in multiple places

Both for the application’s performance and the user’s access to files it is beneficial to save captured images to a phone’s camera roll. Also, material from logs could be stored on a desktop folder.

Integrate to other services

Embedding a log onto a web page could be beneficial for presentation by maker spaces, community forums, and on portfolio websites.

Exporting

Many target users requested the ability to export a log as a PDF document since it is a convenient and trusted exchange format.
8. Multi-media

**Implemented**

Toolbar design
The toolbar has been drastically re-designed (Figure 39, next page). It is now present on all locations in the application, but the content it carries is dynamic. Also, tapping an icon will pop-up a menu that gives you further choosing options. For example, tapping the image icon will now let you choose how to capture the image, either by camera, as a GIF, or from your phone’s gallery.

On the user’s own profile screen the toolbar gives the option to add a new log, search logs, and entering profile settings. On a visited log it only allows the user to copy a link, follow, and manage notifications.

Inside an owned log the user can add new logs, text, and images, and visit the log settings through the toolbar. On a visited log there is no means of adding entries, but the settings menu allows a user to follow, copy links, and manage notifications.

**Implemented/Concept**

Speech integration
Although the interface is not optimal, one has to go to speech input through the on-screen keyboard, it is available for use.

Moving images
GIF animations have been partially implemented. Android users can use this function to shoot 1 second looping animations with their front facing camera. There is no interface for guiding this functionality; selecting the gif option will automatically record an animation as a background process. The lack of feedback during the process is disturbing, but the results are inspiring and make a log feel alive.
9. Confidence

Concept

Worth my time

Users need positive feedback after they have documented activity. This feedback is needed to communicate the fact that their material is valuable. One popular way of evaluating content is by rating, either dichotomously ("liking") or on a scale ("rating"). However, these all include the premise that content could have a low quality and such systems create inequality. One possible alternative that could be useful would be to measure the amount of time that is spent in the log. This would communicate the amount of effort that is being put into the log. We can then choose to assume that amount of effort is correlating with quality. Using time as a variable allow the quality of logs to be evaluated in a less aggressive manner.

Confidence building notifications could take the form of “There was x time of measured activity in your log last week”.

10. Culture

Implemented

Sign up for failure

The assumption is that failure should be accepted from the start. At sign up (Figure 40) new users see a short message that introduces Pelori as a logbook for unfinished business. Hopefully this gives the new user enough stimuli to make a start with documenting their creative activity.

Concept

Kind reminders

Documentation is easily forgotten and ignored, so a gentle reminder every now and them might be in place. There is plenty of reason to evaluate notifications saying something along the lines of “please document”.
11. Knowledge creation

*Implemented*

Combining explicit knowledge can be done through text-based entries, either with or without pasted links.

*Concept*

*Internalization/Articulation*

Annotating an image with a tag could guide the attention of the viewer to a specific area on the image. In the prototype this functionality is only referred to by a “tag image” option in the image entry menus. Opening a new screen for comments could help making the tagging of an image on mobile easier.

*Implemented/Concept*

No more image captions

Image captions have been removed; instead tags and text entries should be enough to accompany the images with information.

*Socialization*

One big issue remains with the socialization processes, i.e. the processes that are commonly used to exchange tacit knowledge or skills. Visual media that is capable of showing the use of body could be a useful medium for this. However, video files are relatively large and could cause some usability issues related to navigation. For this prototype is therefore decided to include GIF animations. This type of animation can be used in a similar way as the image material, is relatively small in size, and loops automatically. It seems an excellent building block of a visual story.

12. Comprehensibility

*Implemented*

Removal of steps

Steps added a layer of complexity that wasn’t grasped by the evaluators. The imagined value creation did not take place and the functionality was therefore completely removed from the application.
USABILITY TESTING

Test Setting
The usability tests were conducted in an academic maker space. This particular maker space has been set up as a Fab Lab and thus offers tools specifically aimed to transform digital products into physical materials. One popular offering is their selection of 3D-printers, and the tests revolved around gaining tool sensibility for these machines.

As was mentioned in chapter 3.2.2.2 staff members of these types of maker spaces are actively interested in p2p learning. This was reflected by the staff members of this maker space being actively and voluntarily involved with the creation of this test. The staff generously shared materials they use to introduce makers to the 3D-printing software during their courses. These were crucial for aligning the tasks in the test with common activities in the Lab.

Test Subjects
For this round of testing five student subjects were selected based on their likeness to the explorer persona that has been described in chapter 4, The Explorer. This meant they were all interested in learning a variety of skills, struggle to document their general making activity, are proficient in using online resources, and are have experienced various forms of making activities, including team work. Another aspect that was important for this test was that they did not have first-hand experience with operating a 3D-printer.

Tasks
During the test sessions the users completed three tasks. I will describe their general structure. The detailed task descriptions and task materials can be found in Appendix F for further, more detailed, inquiry.

The first task was an introductory task, meant to allow the subjects to freely explore the application and its functionality and clarify the expected activity in the later tasks. For this an example log in which the functionality of the application was demonstrated was prepared. The subjects were invited to document pictures and text in the log while practicing the thinking aloud method. The task ended with the user creating their own log for documenting the activity of the following tasks.

The second task challenged the subjects to learn about topics related to 3d printing processes and explore 3D printer software. This was an area that was new for all subjects. The task ended with the subjects printing a 3D model of a Labrador. This new and complex process could be completed after combining knowledge available in a printed booklet and a logged story in the application. The challenge was to structure explicit knowledge derived from a variety of media, apply this knowledge, and document these processes.
The first session expected an individual subject to complete the second task. The third session allowed two subjects to attempt it in a team effort. The second session was the most challenging and invited two subjects to complete the task while communication through the collaborative features of the application.

After task two the subject(s) received a printed 3D model of the Labrador. The author had prepared these printed Labradors beforehand and had left all the support materials that are needed to properly print these objects. The third task invited the subjects to “clean up” their Labradors by carefully removing these supporting materials. During this activity with the new material the subjects dealt with tacit knowledge.

During the first two sessions the subjects were not given any directions on how to do this (task 3a), but asked them to document this physical activity without previous knowledge (task 3b). The third test allowed the subjects to look into the documentation of the previous subjects. This last task was intended to explore the documentation of physical processes with the application, as well as testing the communication of tacit knowledge across sessions.

**Limitations**

By having the users complete a series of three tasks they were able to evaluate the use of the application in a relevant context. Although this context matched with the actual practice of the makers, a one-hour session guided and monitored by a researcher couldn’t possibly compare to a real-use scenario. Limitations were created by the abilities of the prototype, the short timespan, and the lack of a maker community of practice. This is why not all of the directions for the design could be evaluated. The design directions that could not be evaluated are:

1. **Present themselves with profiles reflecting their identity and personal development through a collection of projects and references.** (Profile)
   The subjects were using a profile that was previously prepared by the researcher. Signing up has thus not been tested. But more importantly identity creation takes time so there was no way to see how the identity of the subject was reflected by the profile.

3. **Connect to a history of influential inventors whilst collaboratively exploring and experimenting.** (History)
   The researcher prepared the material the subjects used. The subjects thus didn’t connect to a dynamic community in which members explore and experiment together.

4. **Have the ability to make open collaborative projects and networks feasible.** (Open collaboration)
   The tasks were planned beforehand for a small, limited number of subjects. There was no way to investigate open collaboration in this context.

10. **Maintain appropriate habits that generate mutual respect and trust.** (Culture)
    This is again a direction that prerequisites both an extended timespan and an active maker community.
Evaluation of the findings
The notes that were taken during the testing can be found in Appendix F. To reveal the implications of the findings for the design they are evaluated from the perspective of several design directions. For each of these design directions the relevant activity within the tasks is identified. Reviewing the findings of this activity provides helps to focus and guide the evaluation.

2. Participate in Joint Problem Spaces for structuring problem and solution spaces with different perspectives. (Joint Problem Spaces)

Relevant activity
Both co-discovery task 2 and task 3b offered the subjects situations in which they had to solve ill-structured problems. For this they needed to use creativity and iterate a problem-solution pair together with other people.

One of the co-discovery tests guided the subjects to work synchronously, i.e. in close distance to each other, and allowed them to speak. This meant the JPS was created outside of the app, so it needed to be documented as a separate activity. During the other co-discovery test the subjects were not allowed to speak with each other and were supposed to communicate only through the application as a communication channel. This way the construction of the JPS itself would be the documentation. However, the communication through the application was too tedious to be workable and the subjects were allowed to work synchronously after several minutes.

Task 3 challenged the subjects to document the physical activity of cleaning up a freshly printed model. They had never done this before and there were no directions given, so the task was ill-structured and creativity was needed. Task 3b guided the subjects to previous documentation, which meant they entered an individual problem-solution sphere. This situation gave more insight in how a joint problem-solution sphere can expand over time when people share their efforts.

The activity was intended to evaluate the efficacy of entries and comments in the process of creating a JPS. As was mentioned in Chapter 3 constructing a JPS means a user should be able to
- Introduce and accept knowledge into the JPS
- Monitor on-going activity for evidence of divergences in meaning
- Repairing divergences that impede progress of the collaboration(Roschelle and Teasley 1995).

Findings
The observed behavior during task 2 clearly indicated that the subjects used problem-solution spaces to deal with the ill-structured problem. However, the documented material shows univocally that none of the subjects was able to record this task with the available tools. Even in so far that none of the subjects took initiative to capture the created problem-solution spaces at all. Only the co-discovery pair that worked asynchronously and was forced communicate using the application documented some JPS development related to this task. However, the bugged state of keyboard input and image capture made the use of the application so frustrating that the subjects were allowed to continue the task synchronously. After this switch their JPS developed through their conversation and gestures and they ceased all documentation. Two individual subjects completed task 3a during the first two sessions. In the third test a pair of subjects
completed task 3b. The documentation of task 3 is far more extensive. Although relatively short, and primarily relying on still images the documentation does give an idea of what the activity is about. More strikingly, the documentation of 3B shows a more advanced state of the solution state, the subjects documented the use of more tools. However, since test 3b was only completed by a single pair of subjects, and the sample size of the test is so small this finding is too unreliable to be a base for any conclusions.

The feedback to task 3 identifies the need for a combination of textual and visual media to introduce new knowledge into a JPS. Three subjects addressed the need for title descriptions to accompany their images. The prototype now only allows comments connected to images, but these are hidden on default.

Another concern of the subjects was them missing important moments. They pointed out that the capturing of information is currently only done by taking snapshots (GIF, images) and their activity is continuous. Additionally, the application requires people to use their hands to document, making it physically impossible to complete the task. Workarounds created by the subjects included making images with only one hand, relying on a partner to make images, and making batches of images with the phone's camera application and uploading and describing them later. All the subjects addressed the need for making continuous documentation, such as video capture and continuously available speech capture.

Apart from issues with introducing knowledge, the feedback also pointed out problems with monitoring on-going activity. During collaboration the logs were not refreshed automatically, and the comment icons were not drawing enough attention at places where comments were made. One shared observation amongst subjects concerned the detail on the images. They were afraid to miss introduced knowledge and create problematic divergences in understanding.
5. Exchange skills and norms through mentor-apprentice relationships and creating key documents. (Mentor-apprentice)

Relevant activity
In task 2 users were able to find out how to operate 3D print software through studying the entries in a provided log. This log had recorded a similar 3D printing process of another maker that was more experienced than the test subject. The task was supposed to bring to light how this master-apprentice relationship was temporarily created, how the application facilitated this process, and how this was reflected in the logs. Also, to evaluate the influence of social stimuli, the third task was arranged in such a way that the subjects across the day would be sharing knowledge on how to clean up their 3D printed objects.

The linking functionality to other logs and sources is currently the only element that can be evaluated.

Findings
Apart from a single image from the cover of the booklet, made by the pair of subjects forced to communicate through the application, no reference to used materials has been made. There is no mention of used logs. None of the subjects seemed to be bothered by their lack of referencing during and directly after the log. Their main focus lay by the activity of 3D printing. Two subjects mentioned the need for keeping all attention to solving the problem, and referencing was not a priority in that process.

This de-prioritizing of documentation did not only affect the referencing, but also the creation of dynamic mentor-apprentice relations in collaboration. The subjects communicating through the application had significant trouble to share gained experience. The subject working with the Makerbot software chose to explore the offered functionality, but was not able to relay his understanding and questions to his companion. Instead he spontaneously abandoned belief in the effectiveness of the collaboration and opened Google’s search engine.

6. Intuitively navigate between and within communities and projects. (Navigation)

Relevant activity
In task 2 and task 3b subjects were asked to document activity that was partially guided by other logs. For this the subjects needed to find logs, retrieve information, and return to the documentation log. The elements related to the navigation inside and across logs were reviewed.

Findings
Navigation across logs was made possible by the search functionality. The subjects ran into some bugs during their activities, for instance the search button in the profile view disappeared after opening a log and returning to it. Other bugs included unreliable behavior when retrieving results. A log named “easy 3d printing example” could not be found with the search terms “3d printing” “3d print” or “3d”. Only “3” was able to return the result. Also, the need to re-submit the query after switching filters was bothering both the subjects and the researcher.

Aside from these technical issues a variety shortcomings of the design were brought to light. The search icon, the colored globe, did not communicate its function properly. Three users addressed their confusion to it. A magnifying glass was mentioned as a better solution.
Another design flaw was the lack of information on the search results. The large white space on the right side of the list element was considered a perfect place for a visual clue to a log’s content, like an image. But results should also be evaluated for relevance and quality.

Two users suggested that controlling the search with voice would allow it to become a less tedious activity. One subject believed keywords could also help making the activity easier.

There was also rich feedback on the navigation inside the logs. The inconsistencies in leaving menus and comment sections were a common concern to the subjects. And navigating to the top of a log by tapping the title was considered unclear.

One persistent inconvenience was caused by the way the entries are presented. Three subjects directly addressed their need to have the order flipped, and see the latest entry last in the list. Also the amount of scrolling that was needed to move through the content was considered to be troublesome. One subject recommended using thumbnails instead of showing the full entries.

7. Collect information from and present activity on other platforms. (Compatibility)

Relevant activity
Since the desktop or web-based version was not available at the time of testing linking websites into a log was significantly obstructed. However, the mobile application could prove to be an outcome for documenting knowledge gained from physical information carriers, such as books and instructions. Therefore task 2 included information retrieval from a booklet.

Findings
As was mentioned before the documentation of information retrieved from the booklet was minimal and the process was regarded as too difficult (Figure 42). Surprisingly, the issues with the capture process could, according to the subjects, be solved with a desktop or web-based application. They mentioned that processing the information there would improve the workflow and accessibility of the information.

8. Enjoyable and effortless communication using a variety of media formats. (Multi-media)

Relevant activity
All the tasks tested documentation with a variety of media. The prototype allowed capturing text through keyboard, speech, pictures and GIF animations. Specific interest is paid here to the ease of use of the application and the derived satisfaction.

Findings
The keyboard was considered to be troublesome (Figure 43). It was regularly bugged and typing a word would automatically write some random gibberish. When it was working correctly the bottom toolbar moved up and stayed above the keyboard. This was considered confusing. Also, most tiring, there was no clear ending after the entry had been typed and the keyboard could not easily be closed. The speech input has not been used, even though some subjects were recommending a further implementation of it.
The image capture was bugged too. Sometimes the app would restart after taking a picture, a far from satisfying experience. One subject requested the ability of zooming in pictures.

The subjects eagerly recommended other useful media formats. The continuous voice capturing and video have already been mentioned as useful in situations where manual or difficult processes are involved. But also live streaming a creative process, capturing a screen on a desktop application, and bookmarking to Pelori from a browser were referred to.

9. Establish confidence through documenting and sharing activities. (Confidence)

Surprising finds
Although topic 9 was not intended to be included in the evaluations, a majority of subjects did mention concerns of not being confident enough to share their process. Although the findings do not give any clear information on how this confidence can be created, it does emphasize the importance of this direction.

11. Document the processes of combining, internalizing, socializing and articulating knowledge while sustaining their main task. (Knowledge creation)

Relevant activity
The process of combining of explicit knowledge was tested in task 2. Subjects needed to synthesize what they had learned from the booklet and the log. The booklet and log were created in such a way that using only one of them did not give enough information to complete the task of preparing a model for printing.
Task 3 demanded the subjects to articulate and capture their physical exploration of cleaning up a 3D model in a log. Another subject would attempt to internalize the knowledge from that documentation. Also the idea of socializing knowledge through moving image is explored. More specifically, attention is paid to the effectiveness of current textual representations of combined knowledge, annotated images for articulation and internalizing, and moving images for socialization.

**Findings**
The need to combine many sources of explicit knowledge was addressed by the subjects. However, the application did not succeed in becoming a base to collect all those sources and formulate a new body of knowledge.

The combination of pictures and text were very popular for communicating knowledge. Improvements can be made through image quality, zooming functionality, and adding annotations on and below images. To improve the ease of use speech can be used to directly register comments and questions related to images.

Although none of the users recorded a GIF in their documentation, they were all very convinced of the need for video capture. However, problems with this format were also identified, instead of one long video a recording might need to be divided into several shorter parts. These could then be presented as a thumbnail view.

12. Keep documentation transparent through basic and unified communication and subsections. *(Comprehensibility)*

*Relevant activity*
Task 2 invited the user to learn from a log. But are the qualities of a log sufficient for that goal? And additionally, are the logs created during task 2 and 3 able to communicate the process of the users?

**Findings**
Slightly unrelated to the intended research goals, but still relevant from the perspective of the topic of comprehensibility, were findings related to misunderstanding the functionality of the application. One subject mentioned the relation between the 3D printing and the application was unclear, even after the functionality had been introduced to her. Another subject believed the created documentation was supposed to be as good and polished as a regular tutorial throughout the test.

The comprehension of what is in a log can be improved by changing the organization of the entries. One subject advised that a cover image could help out to get an initial idea of what is in a log. These cover images could also be shown on the search results. Another user mentioned thumbnails could help digest larger chunks of information.

One subject felt the nametag of the entry creator significantly affected his understanding of the content, since it broke the flow of the storytelling.
PART III: RESEARCH THROUGH DESIGN

8. UX THEMES
The prototypes were modeled after the directions formulated in chapter 5. Although these directions were very useful for determining the dimensions of the design, they are far from a comprehensive design brief. Many design decisions that needed to be taken were thus based on assumptions that needed to be validated. The presentation of this prototype during the Maker Faire and the Demo Day helped to validate and revisit made decisions with the target users.

The second prototype synthesizes both the initial design directions and the gained knowledge of the user evaluations. The result of this iteration was tested with a select group of target users. Although these tests were providing very limited information, they remain the only research activity that explores the actual use of the application.

The results from the research through design process can be summarized in the following three themes:

1. Creative storytelling
   Makers iterate as they continuously make assumptions and experiment. For them newly combined knowledge is not directly verified as useful or right. To verify the knowledge has to be applied first. But while applying their new assumptions combine with situational cues and iterate again. So documenting combined knowledge means capturing it dynamically in a process instead as a static given. This understanding within context was what the test subjects tried to retrieve from the logs. But they felt obstructed by a reversed chronological order and other factors that affected the flow of the stories. Regarding documentation as making an ongoing story has been too much on the background during the design process.

2. Natural interaction
   The tests and evaluation validate that makers frequently use JPSs. However, the testing highlights that the involved thought processes are rapid and experienced as complex. It also shows the app is not flexible enough and, even though it is an improvement over other documentation methods, operating it takes to much effort. Both the evaluations and test reveal that there is a need for more natural interactions that are common when constructing a JPS. For one, it should allow the users to keep their hands free so interruptions to their process are minimal.
To express themselves the users regarded the integration of text and image as a must have to clearly communicate progress. The tested applications were capable of creating documentation with those elements. However, none of the users was satisfied with the interaction that was required to make this documentation. Instead they wanted the application to “listen” and “see” them. Both voice capture and videos were a common request.

To fit the behavior and situated needs of the makers there should be an increased focus on the design of the workflow between desktop and the device. Additionally, the more natural ways of interacting could be utilized for rethinking real-time collaboration through the application.

3. A sense of engagement
Recognizing the need for documentation, having the confidence to share work, and wanting to reference other people’s work are likely to be connected to the level of engagement that is experienced. The lack of a community of practice and a real environment might have caused problems during the testing. Any future investigation of these topics needs to include a more relevant social setting.
PART IV: RESULTS

9. DISCUSSION
In the motivation chapter the goal was set to help create a meaningful solution for the lack of documentation by makers. Studying the collaborative practices of makers through user-centered design was supposed to inform recommendations for a system that could make documenting more satisfying and more fun. More specifically, it was assumed that a process combining research for design and research through design could help generate the needed knowledge regarding the desired UX.

To be able reflect on these goals I proceed to answer the main question: “How to design the UX of a multi-platform application to enable it to facilitate knowledge exchange between makers?”.

The design directions formulated in chapter 5 concluded the research for design stage. Being based on both literature and explorative field research, it is clear these address vital areas of attention for the needed design. They were capable of providing the fundament for the creation and iteration of two prototypes. However, they are not comprehensive recommendations for a desired user experience. The relation between the directions is not clear and they thus remain fragments of a holistic understanding.

Fortunately, the research through design stage provides three themes that help iterate the directions. The conclusions on the evaluation and testing with the prototypes in chapter 8 describe the perceptions and responses of makers to the use and anticipated use of the system. It is clear the nature of these findings relates closely to the definition of UX mentioned in chapter 1. Nonetheless, the limitations of the evaluations and tests cause these themes to be far less comprehensive than the directions in chapter 5. The findings of chapters 5 and 8 should be combined to provide a sufficient answer to the main question.

Three recommendations for UX design can be formulated through synthesizing the directions previously identified in this thesis. Applying these UX guidelines to a multi-platform application will enable it to facilitate knowledge exchange between makers:

1. **Stories of creativity**
   The makers want to have fun and develop their creativity. They actively try to gain knowledge of tools and materials. Even though they do not fully understand the problems they face in projects, they get the attitude to solve them. They challenge themselves to iterate possible solutions through experimentation and collaboration. In this dynamic process they share both articulated knowledge and tacit skills through the use of physical space, artifacts, and their bodies. Because these processes are continuous, rapid, and unorganized, a place is needed where their ongoing efforts fit in a unified structure. This structure should make the maker’s story easy to understand and an inspiration for others.

2. **Intuition meets education**
   Makers learn from each other in DIY activities, both online and offline. These activities originate historically from crafts. The traditional learning process remains very similar today; a mentor teaches an apprentice their skill. However, because the DIY activity has become increasingly complex this learning process has as well. Maker projects often involve many mentors for different aspects, engaging in various fields of expertise. Each of these fields has their own knowledge communities, with their own sets of norms, cognitive tools, and artifacts. This requires flexibility because a wide diversity of materials needs to be gathered, processed, and then presented on a variety of platforms.
9. DISCUSSION

Applying this large amount of information practically takes all the available time and effort of a maker. Documenting activity can only be infused in their creative processes if it fits it in a natural way. There is reason to believe that documenting activity has to be similar to Joint Problem Sphere (JPS) creation. Makers mostly create JPSs through talking, sketching, and exemplifying. This existing behavior should be translated to an intuitive workflow cutting across and fitting platforms. A variety of media capture methods are needed to respond to the needs of different contexts.

3. Support structure

DIY activity has a history of influencing commercial products and processes. And makers should be able to feel proud to be part of this. Communities of explorative inventors have a huge potential, but large-scale collaboration is difficult to aim and maintain. One major factor is that these processes can become confusing. The supporting structure to prevent this confusion still needs to be discovered. But this is not the only factor, there are also social reasons obstructing collaboration.

Makers need an environment based on respect, trust and reciprocal action to share their efforts. Because a project reflects the maker’s identity, negative feedback can really discourage a maker to share. But on the other hand, positive feedback is regarded one of the most rewarding experiences. Positive feedback helps to build a maker’s confidence and initiative to share. To make documentation fun, a system should create a positive feedback loop in which makers frequently build confidence and inspire each other. This will generate new ideas and durable relationships.

Looking back on the final results I feel confident that this project has indicated a viable development direction towards a possible solution. The recommendations seem to form a solid base for future design activity. But more important was the feedback from the makers we collaborated with. We have repeatedly received positive and encouraging feedback from the communities we approached. Already during the early stages the relevance and urgency of the topic were often mentioned and this hasn’t stopped. Especially the prototypes, even if they weren’t very usable, were inspiring and univocally seen as a step in the right direction. Of course this isn’t the same as being able to create meaning in a value-in-use process, but our effort seems an important step. A step on which I wholeheartedly hope many more will follow.

However, the results do have their limitations. The process was known to be flawed since the prototypes could not be tested in a real social environment. Additionally, just a small segment of the target user group, only one of five personas, was able to test the application. For future testing I heartily recommend to iterate the prototypes based on the final recommendations and to test it with different personas in different types of maker spaces.

Another flaw arises due to the convergence in this project thanks to the use of single prototypes during evaluations and tests. A future design process could diverge more on how to answer the demands of the final recommendations through comparative tests with a variety of prototyped solutions.
PART IV: RESULTS
10. CONCLUSION
This thesis set out to investigate design solutions for problems related to knowledge exchange activities between makers. Literature research explained the motivation for these activities and elaborated on its complexities. Field research including interviews and co-design sessions revealed the characteristics of the involved stakeholders and their particular needs. This research for design activity was condensed in 12 design directions. These directions informed the design of two prototypes. The first prototype was evaluated on two events, Europe’s largest Maker Faire in the UK and the Spring Demo Day in Aalto’s Media Lab. Feedback from these evaluations were used to iterate the prototype. This second prototype has been used in usability tests in a Fab Lab. These findings in this research through design process exposed three themes related to the desired user experience of a designed solution. Combining the design directions and UX themes provided the answer to the main question of the thesis: “How to design the UX of a multi-platform application to enable it to facilitate knowledge exchange between makers?”

The answer urges designers of systems aiming to facilitate knowledge exchange between makers to pay attention to three topics. The first topic expands on stories of creativity. These stories are the dynamic representations of the learning processes of makers. A story should be able to translate complex and continuous processes into an understandable and inspiring format. The second topic addresses the overlap of intuition and education. Designed solutions need to be flexible since maker projects involve multiple and diverse learning processes. But to be workable users need to be able to interact in a natural way with the solutions. The last topic brings the need for structure and support to the forefront. To tap into the potential of larger collaborative projects a structure should be developed to prevent confusion. In addition to that a positive feedback loop is needed to allow makers to share and build lasting relationships.

These findings add to a body of research on the maker community through exploring the underlying motives of knowledge exchange amongst makers. Additionally, the findings provide a base for future research and design activity. This activity is necessary to reduce the loss of knowledge and develop the efficacy of maker communities. Improving the ability of these communities is expected to have a positive influence on existing industrial processes.


11. REFERENCES


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