Re-designing prototyping tools

A study about how to facilitate visualizing ideas and building prototypes

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Abstract

This paper investigates how physical prototyping modules can be designed to facilitate for interaction designers to visualize their ideas early on in a design process. As technology is getting cheaper and easier to use, it has opened up the possibility for others than just engineers to build with technology. We see technology being more and more used by designers for building prototypes and testing ideas. A setback with using technology is that it is time consuming and error occurs easily. By testing a set of three prototypes I will investigate the problems at hand for interaction designers and come up with a design solution to facilitate their design process. I will come to conclusion about making the modules flexible, functional and user friendly to meet the user’s demands.

Keywords: Tangible user interfaces, physical prototyping, prototyping modules, user-centered design
# Table of Content

1. Introduction ............................................................................................................... 4
2. Background .................................................................................................................. 4
   2.1 Background & Motivation ...................................................................................... 4
   2.2 Purpose ................................................................................................................. 5
   2.3 Research Question ............................................................................................... 5
   2.4 Target group ......................................................................................................... 5
   2.5 Limitations ........................................................................................................... 5
3. Theory .......................................................................................................................... 6
   3.1 Interaction Design and Visualization ................................................................. 6
   3.2 Physical Prototyping ............................................................................................. 8
      3.2.1 Lo-fi ............................................................................................................... 8
      3.2.2 Mid-fi ......................................................................................................... 10
      3.2.3 Hi-fi ............................................................................................................ 10
   3.3 TUI ......................................................................................................................... 11
   3.4 User Centered Design ......................................................................................... 11
4. Examples of related work ............................................................................................ 12
   4.1 littleBits .............................................................................................................. 12
   4.2 Makey Makey ..................................................................................................... 13
   4.3 Arduino .............................................................................................................. 14
   4.4 TinkerKit ............................................................................................................. 15
   4.5 BASIC Stamp .................................................................................................. 15
   4.6 Processing .......................................................................................................... 16
5. Methods ....................................................................................................................... 17
   5.1 Literature Studies ............................................................................................... 17
   5.2 Concept development ......................................................................................... 17
   5.3 Prototyping ......................................................................................................... 18
   5.4 Interviews .......................................................................................................... 18
   5.5 User testing ....................................................................................................... 18
   5.6 Brainstorming .................................................................................................... 19
6. Design process ........................................................................................................... 19
   6.1 Research ............................................................................................................. 20
   6.2 Literature ............................................................................................................ 20
<table>
<thead>
<tr>
<th>Section</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.3 TinkerKit e-mail</td>
<td>20</td>
</tr>
<tr>
<td>6.3.1 Result of the TinkerKit e-mail</td>
<td>21</td>
</tr>
<tr>
<td>6.4 Interview</td>
<td>21</td>
</tr>
<tr>
<td>6.4.1 Result of the interview and the e-mail</td>
<td>22</td>
</tr>
<tr>
<td>6.5 Concept</td>
<td>23</td>
</tr>
<tr>
<td>6.6 User testing 1 &amp; Workshop</td>
<td>26</td>
</tr>
<tr>
<td>6.6.1 Result of user testing 1 &amp; workshop</td>
<td>28</td>
</tr>
<tr>
<td>6.7 User testing 2</td>
<td>30</td>
</tr>
<tr>
<td>6.7.1 Result of user testing 2</td>
<td>32</td>
</tr>
<tr>
<td>6.8 User testing 3</td>
<td>33</td>
</tr>
<tr>
<td>6.8.1 Result of user testing 3</td>
<td>34</td>
</tr>
<tr>
<td>6.9 The final design</td>
<td>35</td>
</tr>
<tr>
<td>7. Discussion</td>
<td>36</td>
</tr>
<tr>
<td>8. Conclusion</td>
<td>39</td>
</tr>
<tr>
<td>9. References</td>
<td>40</td>
</tr>
<tr>
<td>Appendix 1</td>
<td>44</td>
</tr>
<tr>
<td>Appendix 2</td>
<td>45</td>
</tr>
<tr>
<td>Appendix 3</td>
<td>46</td>
</tr>
</tbody>
</table>
1. Introduction

The interest and possibility of creating your own prototypes in a cheap and easy way has emerged steady since the introduction of Arduino and other prototyping platforms to the market, which has given inspiration to the subject of this thesis. The bar has been lowered to the extent that none-professionals have the same access as professionals towards hardware and visualizing their ideas. But it still requires basic knowledge in programming and combining hardware together, which can mean that creating a prototype and visualizing an idea can take a long time for the designers. Especially when only trying out a concept or an idea and you want to get feedback and input fast, to see if the concept works or not, in an early stage in the project.

I believe this is an interesting and expanding field which I want to examine further from an Interaction Designers point of view. When designing products in the field of Interaction Design (IxD), both for bits on your computer screen and for your smartphone or even for physical objects, the usability and user-centered design (UCD) are core components in the design discipline (Saffer 2010). In this thesis I want to integrate IxD thinking with the aspect of designing a user friendly and usable tangible user interface (TUI) to facilitate an easier and faster way to try out your ideas without the need of knowing much about building prototypes.

I will start this thesis by presenting the purpose behind the project and the question which I am basing my thesis on. Afterwards there will be a review of the methods used in the project. After this follows an overview over the research process and the user tests and then the result gained from the user tests will be presented. The thesis ends with a discussion section and a conclusion of the project.

2. Background

2.1 Background & Motivation

Electronics and building prototypes has for a long time been limited to engineers and professionals. Where access has meant a high learning curve for being able to build and create with technology. But since the introduction of cheaper and more easy-to-use technology, it has enabled people without any previous knowledge to start creating and programming themselves. This has started to change the way we see technology and it is not restricted to professionals or companies anymore, now children can quickly learn how to program and create their own electronic projects at home.

Designers are a group which could benefit greatly from this when creating and testing a concept. The ease of use makes it ideal for rapid prototyping an idea. I want to examine the possibility of improving
and re-designing physical modules which enables designers to visualize their ideas in an early stage of a design process, without the need of building with electronics.

### 2.2 Purpose

The purpose of this thesis is to research the possibilities of implementing a tangible user interface to facilitate creative design processes when building prototypes. I want to investigate how you can improve prototyping modules and to make them more usable and easier for interaction designers to use for testing and visualizing ideas. By doing so, time and effort can be focused on further developing an idea, instead of focusing on building prototypes.

### 2.3 Research Question

The question which has inspired the work of this thesis is as follows:

*How can prototyping tools be re-designed to facilitate the ease of building and testing ideas early on during a design process for interaction designers?*

### 2.4 Target group

I have chosen to include two target groups in this thesis. The first is a professional designer from a company based in Malmö, Sweden, who is daily working with creating prototypes for their projects. The second group is design students whom are currently learning to design and create prototypes. I have chosen these two groups of users to get a broader mindset and different experiences and knowledge with creating and working with prototypes. This will give me two different perspectives of the subject at hand into my thesis.

### 2.5 Limitations

I have chosen to limit myself to interaction design students from the University of Malmö, Sweden and to the locations in the university which they are the most familiar with. I have extended my thesis to also include a professional designer, the interviews and user tests have all been conducted at his office in Malmö, Sweden.
3. Theory

In this section of the thesis I will go through the theory regarding interaction design, theory about tangible user interfaces and the concerns which the researchers are acknowledging, prototyping and how it is being used and also user centered design. This will act as the theoretical foundation which will give me a good base to stand on throughout my research.

3.1 Interaction Design and Visualization

We use interaction design for designing technology to make it more user friendly to people and to make technology make more sense for people. Designing and creating physical products has been a big part of the field of Interaction Design ever since the beginning of the 90s when it first was established as a separate design field (Saffer 2010: 8). Different ways of expressing an idea and visualize them has always been around, where different tools for helping the designer create sketches and prototypes has evolved steadily beside emerging technologies. Being able to visualize an idea and to make it tangible is an important part for the designers when creating prototypes of physical products. Buxton argues that sketches and prototypes are separated into different stages of the design process and serves for different purposes (2007: 139).

![Figure 1](Image)

*Figure 1 Illustration of when sketches are used and when prototypes are created. (*Buxton 2007: 138 *)

As the diagram suggests, the red part of the x-axis is where many ideas and concepts are being created and generated to fast get an understanding of which concepts should be discarded and which should be
iterated. This stage of the diagram is where sketching has its great potential for generating ideas and where iteration is cheap and simple. The further into a design process you get the less iteration happens and the design is starting to take its form to eventually become a physical prototype.

When designing for people, having in mind how we use our natural properties and how we interact with our world is necessary, as Norman puts it. The design should be natural and simple enough for the users to understand without the need of looking for instructions on how the product works (2002: 188). According to Buxton, even though the design process and our work result in a physical product we are actually designing an experience for the users (2007: 127).

Through Interaction Design you create user friendly and usable products which are easy to understand, which means that you should design products that users can figure out how they function themselves and to be able to understand what is happening with the product they are interacting with (Norman 2002: 188). But to be able to create as good and functional products as possible it is important to have a good structured base to stand on. Norman pinpoints some principles of designing for users, where he argues that making the functions and actions of the design easy to understand and visible for the users are important for making the interaction between the users and product work well (2002: 188).

With new tools such as Arduino (Arduino.cc) and Makey Makey (makeymakey.com), Interaction Design has moved into electronics and isn't any more confined to a computer screen, smartphone or display. The electronics and technologies are being created with an Interaction Design perspective, to create user friendly and easy-to-use technology, which opens up greater potential for designers and people to interact and create by themselves. An increase of interest in creating your own prototypes and the ability to hack things has opened up a new kind of designers, the makers and the maker movement. With this movement and with open source, a democratization of technology is happening where the people change the way they engage with technology which opens up for a demand of new tools and new design opportunities (Tanenbaum, Williams, Desjardins & Tanenbaum 2013). New technology is emerging making more tools available for more designers. From an Interaction Design point of view, this gives way to create new user friendly tools for a bigger audience.
3.2 Physical Prototyping

“If a picture is worth a thousand words, then a prototype is worth 10,000. Prototypes go beyond the power of show and tell — they let you experience the design.”

(Zaki Warfel 2009: 5)

When wanting to visualize a design idea or concept a good start would be to prototype it. Prototypes can take many different forms and functions, this all depends on what the designer is after and what the product or service is designed for (Saffer 2010: 174). In general prototypes are used as a tool of communication between designers and stakeholders, at the same time it is a tool for the designer to visualize an idea (Rogers, Sharp & Peerce 2011: 390-391) and to make it more tangible, something you can feel and experience (Zaki Warfel 2009: 4). Prototypes are used by designers to support them in design decisions and help them find answers to design problems which might occur (Rogers, Sharp & Peerce 2011: 390-391). They communicate not the solution of a problem but rather a possible solution of a specific problem.

When building prototypes to see what work or don't work as a solution to a problem, the designer should create multiple types of prototypes, which all have different goals for the designer to try out (Saffer 2010: 177). Often a prototype does not include all aspects of the final product, but instead it is often used to visualize and focus on a few specific components (Saffer 2010:177). Occasionally, one prototype can be the perfect solution for a problem, but more likely, there will be different parts of different prototypes which work great (Saffer 2010: 177). This means combining these parts into a new prototype, “a hybrid of the other” as Saffer puts it.

Todd Zaki Warfel mentions in his book, Prototyping: A Practitioner's Guide the value which lies within the usage of prototypes. The simple fact that it takes you further than text documents and words trying to describe something tangible, which can be hard to grasp (2009). The potential lies in being able to interact and experience the prototype and the proposed design idea. Letting users play with it and try it out makes it easier to comprehend the use of it, but it also acts as a good playground for testing out an idea (Zaki Warfel 2009: & Saffer 2010: 177).

3.2.1 Lo-fi

Usually prototypes are divided into a specific category depending on how advanced and interactive they are. A prototype which is static or very limited in its interactions and which often require a person to make it interactive and to fake a function, is a so called “lo-fi” prototype or low fidelity prototype
(Saffer 2010: 177). These lo-fi prototypes are commonly created by paper, cardboard, clay and other cheap and easy to throw away materials which are simple enough to be quickly modified (Rogers, Sharp & Peerce 2011: 391-392 & Saffer 2010: 178-179). Designing a lo-fi prototype is usually done in an early stage of a design process, normally during a concept development stage (Rogers, Sharp & Peerce 2011: 391-392). Where they are usually rapidly put together and where they often look “crude and unpolished”, to quickly be created for testing a concept and just as easily be thrown away (Saffer 2010: 177).

The goals for the designer for using lo-fi prototypes can be to test form, size, shape, weight and possible locations for different components (Saffer 2010: 178-179). In this stage of the concept development, idea generation and getting rapid feedback is key, therefore quantity is better than quality (Zaki Warfel 2009: 31), the more examples of possible design solutions the better. Because of their simplicity they provide very low or none expectations from the users when tested (Saffer 2010: 177-178). This opens up the possibility for feedback and criticism by the user, regarding the components being tested, Saffer continuous.

Rogers, Sharp & Peerce brings up in their book Interaction Design: Beyond Human-Computer Interaction the disadvantages with the usage of lo-fi:s, where they argue that they are limited in their usefulness for usability testing and that you can only go so far with a lo-fi prototype, when the expected requirements have been reached, they easily loses its utility.

\[\text{Figure 2 Shows sketches on lo-fi prototypes (Peerce, Rogers & Sharp 2011, 394)}\]
3.2.2 Mid-fi

Mid-fi is a relatively new terminology for explaining a prototype which McCurdy, Connors, Pyrzak, Kanefsky & Vera puts it; “mixed-fidelity, that is, high-fidelity on some dimensions and low-fidelity on others.” What they mean by this statement is that only using lo-fi and hi-fi is insufficient to gather all types of prototyping methods and approaches in one spectrum used by designers today (McCurdy et al. 2006). Using the terminology of mid-fi should represent a prototype which functions well in some aspects of the design, but lacks interactivity and functionality in others. Some argue that having different types of characterization of what stage a prototype is in and how finished it actually is, can be very misleading and be hard to grasp, especially for the users and stakeholders, whom are not used to this types of characterization (Houde & Hill 1997). People have different expectations and understandings towards the fidelity of prototypes, which means that for one person a lo-fi, can be a mid-fi or hi-fi for another person, depending on what they expect and how much knowledge they possess.

3.2.3 Hi-fi

The hi-fi prototype is generally more advanced, with more specific part of the prototype working. This makes it good for trying it out on users to get feedback on technical issues (Rogers, Sharp & Peerce 2011), which could include, the layout, the placement of buttons and how the interaction functions. Compared to lo-fi, which can easily be modified and thrown away in an instant, hi-fi prototypes according to Rettig, take long time to build which makes the iteration of the design process and the amount of re-designs, implementations of new features or removal of undesirable ones limited (1994). Once a hi-fi prototype is designed it automatically makes it harder to change things if necessary. Not only is it harder, the willingness of designers to change their prototype is often resisted (Rettig 1994). If a prototype is too much alike the final product or solution, there is a greater risk for it to be thought of as the real product (Saffer 2010: 179-180). This can lead to users not being to willingly to critic on the specific aspects the designers are testing. Therefore setting the correct expectations for the user before letting them test it is vital, it should clearly state that it is a prototype and not the end product (Saffer 2010: 179-180).
3.3 TUI

Tangible user interfaces or TUIs have been around for quite some time but it was first defined as a concept by Ishii and Ullmer when attempting to find ways for interacting with digital interfaces and products while using tangible bits (1997). Along with the emerging field of Internet of Things (IoT) which indicates that a new era of technology will be about connecting physical objects to the internet (Wikipedia 2014). Here the TUI that the users are interacting with will become a much more important part of the development of products and devices.

Research has shown that TUIs have an advantage for enhancing learning new things and remembering different tasks when compared and tested against Graphical User Interfaces (GUIs) (Patten & Ishii 2000). The potential that lies within TUIs and which GUIs lacks is that it takes advantage of human skill set of interacting with physical objects. By human nature we are built to perceive our surrounding environment with our senses, by touching objects with our hands we can gain knowledge and understanding regarding different objects. Through the implementation of TUIs, Fitzmaurice, Ishii & Buxton argues that we open up the possibility of interaction with two hands, compared to the GUIs one hand interaction, where it is possible to only do one interaction at the time. This allows for parallel input and serves for collaborative use (1995).

Even though there is evidence of TUIs being a better solution in different aspects and the fact that it takes advantage of natural human skill sets, it is often considered very hard to actually implement in our everyday lives. Problems regarding this might be that they are too specialized to function in a very limited context. The potential of many people working with TUIs and creating their own working prototypes is very restricted due to lack of programming knowledge and a high learning curve regarding hardware (Gandy, Jones, Robertson, O’Quinn & Johnson 2009).

3.4 User Centered Design

User Centered Design is a design discipline within the field of Interaction Design, where the focus lies on creating products and services aimed for the user, to provide as good interaction and user experience as possible. Designing for users can mean eliminating a specific problem or designing to help the user finish a task or reach a goal (Saffer 2010). An example of that could be buying a train ticket from a machine at a train station. The goal for the user would be to get the ticket and the goal of the designer would be to make the interaction of buying a ticket as smooth and easy as possible, with as few steps of buying the ticket as possible.
Saffer argues that in getting the information which is needed for creating as good and user friendly product as possible, the best is to involve the specific user in all the steps of the way. From ideation and concept development where the user helps creating concepts and where the feedback tells you if this is something the user would want to use. All the way to building the prototype and also during the final steps before finalizing it (2010).

As people aren’t prepared to spend a lot of time learning how to use new products or systems, designers must design for them so the interaction between the users and the products work well, making the products and systems easy to use. If there are no people there using them, neither the system nor the product is complete (Moggridge 2007).

Alan Cooper argues in his book The Inmates are Running the Asylum that when trying to design for a wider audience of users, you will be less successful, as if you would be if you concentrated your design to one person. When trying to please one group of people, there will be another group disliking it, which can result in a product which no one wants to use (Cooper 2004: 124-125).

The data received during the user tests are a crucial part of the continued development of the product. Analyzing the data will tell you what the user wants and needs, what goes away and what maybe should be implemented to create an ever better experience for the user (Saffer 2010).

An important aspect to have in mind when using the UCD method while designing, which Saffer emphasizes greatly, is the fact that the designer isn’t the actual user (2010). This means the role of the designer is simply to find out what the user wants in the specific product or service and design for it so it becomes user friendly and usable.

4. Examples of related work

Here I will go through projects which represent different ways to use technology for visualizing ideas, which are related to the subject of this thesis.

4.1 littleBits

As small intuitive blocks, littleBits are electronic modules designed to facilitate prototyping, learning and just playing around with technology. With the benefit of never having to do soldering or
programming (littlebits.cc). littleBit is aimed for learning about electronics and technology for both juvenile and adults, the different modules all represent different components such as, thresholds, buttons and motors for teaching how to build circuits and how they work.

*Figure 3 littleBits components (littleBits.cc 2014)*

### 4.2 Makey Makey

The Makey Makey platform enables anything in your surrounding environment, wood, humans, plants to be turned into a tangible user interface and to control and interact with any software you want (Beginner’s Mind Collective & Shaw 2012). With the Makey Makey the user does not need to know the basics of programming or having knowledge in working with electronics. Once connected to a computer, it can be used immediately which makes it ideal for beginners to start interacting with technology, but it’s also very useful for professional designers to help generating ideas and making simple prototypes. It gives the user an immediate possibility to explore and create, and because of the ease of use, it facilitates creativity and lets the user focus on creating, instead of assembling electronics.
4.3 Arduino

This is an open-source prototyping platform, called Arduino. There are different types of microcontroller for different use and there are also a lot of shields which are meant for different purposes, ranging from connecting the Arduino to the internet, to being able to send and receive SMS from the Arduino (Arduino.cc, 2014). This prototyping platform has opened up the possibility of creating your own projects and connecting your surrounding environment to your computer using different sensors and making it possible to create your own interactive objects. The programming environment makes it easy to learn basic programming for controlling both input and output, receiving data and manipulating it. The idea of Arduino came about when they wanted to create a platform for which their interaction design students could use, which would be simple enough for anyone to interact with and build things with, without having to be an engineer to use it (TED 2012).
4.4 TinkerKit

As part of the Arduino family, the ThinkerKit enables users to quickly learn about electronics, without needing to soldering or for that matter use breadboards. Everything is greatly emphasized in making it easy to work with electronics and to lower the bar for beginners but also facilitating for experienced users as well (tinkerkit.com).

![Tinkerkit module and shield for Arduino uno](tinkerkit.com 2014)

4.5 BASIC Stamp

The BASIC Stamp is just like the Arduino, a microcontroller, which was created in the early 1990's which opened up the possibilities for people to get into electronics and making it 'easy-to-learn'. The microcontroller runs on the BASIC Stamp Editor Software with which you can control anything from sensors to robots (parallax.com, 2014). This microcontroller is used by designers and hobbyists who have an interest in learning about technology and building their own circuits and prototypes. It facilitates easy interaction and makes building simple for beginners and designers.
4.6 Processing

Processing is a programming language and a software sketchbook which is being used for learning, sketching down ideas and building prototypes. Its simplicity and easy-to-learn language makes it suitable for students, hobbyists and also professionals to create and build their own projects (processing.org, 2014). Processing aims towards facilitating for designers and visual artists to create and sketch down their ideas in code, with the benefit of not having to write much code.
5. Methods

In this section I will go through the different method which I have chosen to use for conducting my research. I will later in the design process and in the discussion relate and reflect upon the choices of my methods.

5.1 Literature Studies

I have read books, papers and articles in order to get an overview and knowledge on the subject at hand, which has been a very important part of the project. Even though this is an interaction design thesis where the emphasize lies in creating and building a project, this wouldn't have been done without a proper research in the field of interaction design. To be able to contribute with a little bit of new knowledge to the field of IxD it is essential to understand and know what others have done and researched in the field before. Topics of tangible user interfaces, prototyping and user centered design has helped me create the base for my thesis and prototypes.

5.2 Concept development

When developing a concept for a product or service, a good start would be to start with ideation. Where the sole purpose is to generate as many concepts as possible and where there are no bad ideas. During the concept phase all ideas should be welcomed and considered and not discarded. The value in this lies in getting a greater spread of ideas and different views for possible solutions. An important aspect which Saffer (2010) argues is to sketch down ideas fast on paper without describing them with words. An idea should as far as it can only be visualized, then be set aside to leave room for new ideas. He also says that avoiding technology when generating ideas is vital for the creative process, where using technology only will get in the way and slow things down.

In this thesis I will start with creating concepts based on the theory and knowledge I have gathered in my research and interviews, I will later chose one of the concepts to proceed with and create prototypes and test these with different users to get an understanding of what users need and want to make the prototypes answer to their demands.
5.3 Prototyping

Sketching has been used throughout this thesis but mainly in the beginning of the design process, where generating many ideas is crucial. Sketching has its benefits of being cheap and simple to do. With sketching you can easily communicate and visualize a concept without putting much effort into the project (Buxton 2007: 139).

Lo-fi prototypes were used in the beginning of the design process to help illustrate the concept and to open up the users for criticism and make them get involved and interact with the prototypes (Saffer 2010: 177-178).

Mid-fi prototypes were used to help visualize the interaction and make the users understand the interaction better and also to invite them to actually interact and grasp and feel the concept and not only have it described to them (Zaki Warfel 2009).

5.4 Interviews

When choosing to interview users it’s important to have in mind what the purpose of the interview will be. There are different approaches and types of interviews which are used for different purposes. Fontana and Frey (1994) mentions four interviewing methods, structured, semistructured, unstructured and group interviews. If the purpose is to get an idea of what the user likes about a design idea or more general thoughts, an unstructured interview will provide that. In a structured interview there are pre-established questions the interviewer wants to get answer on. This method is commonly used when wanting to get feedback on a specific design or layout, which the user gets to interact with. Semistructured interviews were conducted at the beginning of the design process, where the goal was to get a good understanding of how the interviewee was working in a design process and how the usage of sketching and prototyping was conducted in an early stage. Therefore was both structured questions and open question an important part of the interview session.

5.5 User testing

Testing out your concept is an important part of the design process when creating a product or service. Therefore can user testing be of good use when wanting to get feedback from a design idea or a
prototype for evaluating if the product would be usable and would meet the user’s requirements. But also if it would be something the intended users would consider actually using (Rogers, Sharp & Peerce 2011: 476-477). During a test with a user it can sometimes be useful to let the user think aloud and share their thoughts and ideas with the designer to let them understand what the user thinks and how the user perceive the product or service.

To get feedback on how the concept of the thesis would be perceived and to see if the prototype would meet the user’s requirements, I therefore conducted several user tests regarding both the lo-fi prototype and the mid-fi prototypes. Where the goal of the lo-fi was to get an overview and feedback on how the concept was perceived by the intended users, whereas the user tests of the mid-fi prototypes was to get feedback regarding the interaction and usability of the prototype.

5.6 Brainstorming

The hardest part when conducting a brainstorming session is to actually start (Saffer 2010: 119-121). When wanting to generate many ideas rapidly in a short period of time, brainstorming can be very useful. Often when people need to create ideas through brainstorming a problem that is often reoccurring is that they limit themselves and their imagination by following the conventions of how they have learned how technology works. A way to help you become better at conducting brainstorming sessions is to be more structured. By this Saffer means that it is better to have the structure of the session already set. Where you limit the brainstorming to 30-60 minutes and where you distinguish the problem at hand and how to work around it.

In this thesis I have conducted three brainstorming session separately. The first one was to generate a basic design idea of the lo-fi prototype. The two other sessions was to iterate the design idea from the user tests I conducted from the previous prototypes.

6. Design process

In this section I will go through the process of designing a possible solution for my thesis. I will start by implementing the different methods in chronological order in which I have conducted this process. I will go through the different steps from interviews, concept development to user testing and analyzing the result and in the end present my design solution.
6.1 Research

Research was conducted to get a greater and deeper understanding towards the use of visualization tools and how people and designers were using these in their regular environments. The positive and the negative aspects of using different visualization tools were an important part of the research in order to find out what works and what doesn't.

I will now go through the research methods which I used for gaining more knowledge from and the result of them, which later influenced me in my concept development stage of the project.

6.2 Literature

I started my research by reading books, papers and proceedings to get a broader mindset and knowledge regarding the field of interest. This gave me insight of what has already been tested and investigated, which in turn gave me a good standing point to proceed with my own research and to test my own concepts of a possible design solution.

6.3 TinkerKit e-mail

As I mentioned above the TinkerKit are modules for the Arduino platform enabling the user to build without the need of soldering or use breadboard. TinkerKit among other platforms has inspired me to write about physical tools for visualizing ideas and building prototypes. I contacted them by writing an e-mail asking questions regarding their products, how they came up with their concept, feedback from the users, what they like and don't like about the modules, etc. The reason for the e-mail was to get an understanding of how a platform like TinkerKit has opened up the possibility for more users to learn and interact with electronics. I wanted to see if there were something I could take with me into my own project, which is aimed to be designed to work for interaction designers in particular. They said they had gotten feedback from their users saying that the connectors (wires) are bulky and hard to connect to the TinkerKit shield and that probably their biggest problem was that the modules were a bit expensive. New sensors and modules were considered to be launched to the market and to possibly lower the price of the modules to match the user’s demands.
6.3.1 Result of the TinkerKit e-mail

The knowledge which I can take into account is to make the prototypes easy to use, simple to connect to microcontrollers, but as this being a thesis, I will not take prices into account while creating my prototypes and conducting user tests.

6.4 Interview

I contacted several Malmö based design companies which I had chosen based on the nature of my project and their potential interest in the project. The purpose with getting in contact with these companies was to get an insight of how they were using different design methods and ways of visualizing an idea or a concept. This maybe could give me an idea of how to proceed with my project and maybe shed new light on things I not yet had thought of.

Of the companies I contacted only two replied back and were interested in my project. Of these two only one was interested in letting me interview them. To the company which only was interested in answering questions through e-mail I send the same questions as I brought with me to the interview. The questions were structured in a way so that the respondent could not only answer with a 'yes' or a 'no', but rather force them to express themselves more. The benefit with doing the interview was that I could ask follow-up questions of what the interviewee answered, which wouldn't have been possible in an e-mail. Because of the interview was conducted in Malmö, Sweden I therefore chose to have the questions and discussions in Swedish, which was the native language for us both.

The interview took place in the interviewee's office, which was a comfortable and safe environment for both me and the interviewee and where we wouldn't be interrupted. Because I was alone when conducting the interview I asked for permission to record the entire interview, which lasted for 30 minutes. I also used pen and paper to quickly write down notes of what the interviewee said. I chose to record because of the risk of missing out on information if I only would have used pen and paper. As stated above, I used semistructured interviews, where I had 6 already set questions for getting out information I had already thought of. When conducting an interview it can be easy to slip into asking leading questions about things you want to find out or get answer on (Ejvegård 2003). This is important to have in mind when conducting interviews and to try to avoid them as much as one can. This was backed up with unstructured questions which I thought up as the interview passed. Ejvegård argues that when conducting an unstructured interview, you engage and allow the interviewee to
answer as much or as little as one would want, which can result in valuable knowledge (2003). I started the interview by presenting my idea in person, where upon he could ask me questions about my project. This was done to be sure that he had understood my project and my intentions for the interview. Thereafter I asked him to talk about what methods he used and how a design process for him looked like, thereafter I continued with more questions. After the interview I sat down to rewrite my notes and thereafter I listened to the recordings which I used to fill in gaps in my notes. The structured questions I used in the interview and in the e-mail can be found in the appendix 1. The result of the questions can be read in the next section.

6.4.1 Result of the interview and the e-mail

From the interview and e-mail I distinguished a few important aspects of visualizing an idea and working with prototypes.

**Concept idea:** The interviewee mentioned that creating prototypes is a good way to get an overview of how a concept could work out. This was important for him when working with a costumer, where you through a prototype could generate the general idea to the costumer, before starting to create a more detailed solution.

**Understanding:** Making sure that the persons involved in the design process and the costumers are all on board with the project was a very important statement. Everyone should have a clear view of what should be done. By visualizing an idea you can easily avoid misconceptions, which otherwise could lead to different ideas of what the product should look like.

**Correct expectations:** The interviewee mentioned that he had had a few bad experiences when working with costumers who weren’t familiar with working in a design process. He hadn't clearly stated the state the prototypes were in; therefore the costumer had expected highly functioning prototypes. But instead they were only wireframes, which led to a range of misconceptions and unnecessary work, which the interviewee says could have been avoided if he had given the costumers the correct expectations to begin with.

**Tool for one purpose:** One tool should cover one need in a design process. One tool for all projects and solutions according to the interviewee would only make it harder to create and it would take longer time to get things done. Having different tools for different purposes makes it easier to generate ideas.
The feedback I got from analyzing the content collected from the interview and e-mail helped me get an idea of things to consider when creating the concept of the design idea:

- It should be simple enough so everyone involved understand the usage of it and how to interact with it.
- The prototypes should give the users an impression of being lo-fi/mid-fi, to give them the right expectations.
- One module for one purpose.

6.5 Concept

After thoroughly analyzing the knowledge I collected from the e-mails and interview, I could start my session of brainstorming and concept development to generate concepts of how a possible design solution could potentially look like. I will here present the ideas of concepts that was generated and from which I later chose one concept to continue with user testing, questioning and analyzing.

Concept 1

The first concept was thought up from the idea of having one tool for one purpose. That one component is meant to be used for one thing, which would make it easy-to-use and to have a clear purpose with the interactions of other components. The idea was for it to be pre-assembled with no need for building or soldering, where you only would have to connect the modules to a microcontroller and upload the code onto it for the module to work, a so called; “plug & play” interaction. As my research has shown that creating tangible user interfaces can be very hard to design for, where changing a physical interface can be tedious or even destroy an already functioning product or system (Gandy et al 2009). Therefore the concept was thought up as a simple system for helping to generate an idea, without the possibility of changing the components themselves, but instead replace them with others if necessary. As you can see in figure 9 the sketch shows modules which resemble the TinkerKit modules, where there is no need for soldering or having much knowledge of electronics. The concept aims to have a simple look to it, to make the impression of it being lo-fi come through.
Concept 2

My second concept sprung out of the first concept as a counterweight where as opposed to not being able to change the interface and have components set for a specific purpose or task. In this concept I put the value in the possibility to change the components and interact however the user wanted it to work. Therefore the idea was to design for a dock where different electronic components could be used for different purposes. An example would be as in figure 10 where you connect a button in one dock and connect a led in another dock to easy create a connection for turning a led on and off. Connecting the modules to a microcontroller was thought to be done as in concept 1. This was thought to open up more possibilities for different components being connected with each other, but it would also force the user to have the electronic components in their possession in the first place.
Concept 3

In the third concept I tried to move away from the idea of having to write code in some way. The concept doesn't follow the conventions of my research and the thoughts and knowledge I received. As Ishii and Ullmer state, once a physical interface has been created it is very hard to take the same interface and re-use it with new software and with another purpose (1997). The idea I wanted to capture in this concept was to be able to change the values and thresholds of the different components so that they could be re-programmed with different values to create different purposes depending on the project, without actually having to type a single line of code. Figure 11 shows a sketch of an idea for the concept, where you place the component in one of the sections available on the “breadboard”. Then you use the up and down arrows to navigate through which component you want to interact with. When the specific component has been selected you decide what threshold you want the component to receive by using the other up and down arrows as shown in the image.
Concept of choice

After going through the different concepts and my research I decided to proceed with concept 1, because of the Interaction Design aspect and from the extended research in the field, where it's important to make technology simple, usable and user friendly (Saffer 2010). Compared with the other two options where they demanded more from the users, where changing the interface could make it more complicated and tedious to work with. When testing an idea the user wants a simple and clean work process which shouldn't be interrupted by working with technology.

6.6 User testing 1 & Workshop

To get more feedback and insight in my thesis to be able to choose which direction I would take for my project, I decided to test my concept with real users, whom all had different levels of experience in building prototypes. I decided to conduct user tests and workshops together while interviewing the users when interacting with the lo-fi prototypes and letting them think aloud. The reason for testing the lo-fi prototype was to get an overview and feedback on how the concept would be perceived and if this was something that would interest the users. I wanted to understand what the users thought the concept could be used for, what technology they would want to use themselves in their design work. I wanted this test to be much about discussing their thoughts and ideas on how they work with prototypes, what they think works good and what works bad for them when creating and designing their prototypes. What they want to improve with the different aspects of building prototypes and visualizing ideas.

For the first user tests I created a lo-fi prototype, which consisted of simple sketches of different electronics components on paper, I chose to create a paper prototype because of the benefits that lies behind it. It's very easy to create and can easily be thrown away (Saffer 2010: 177). With paper it's also easy to modify the prototype, add things or remove things from it, as compared to a hi-fi or mid-fi prototype, where changing things can be tedious and hard work.
The user tests were conducted with four design students and one professional designer working in Malmö, Sweden. The students were at the time pursuing a degree in Interaction Design, where they learned how to visualize their own ideas and build physical prototypes, but where they also learned to create wireframes for web and applications. The design professional which I interviewed also participated in all the user tests. The reason for his interest in my thesis was because of his background as he had worked with designing and creating physical prototypes.

The tests took place at the university and at the designers company and were conducted one user at the time. In all user tests I started with explaining my concept idea and the purpose of the test in which they were participating in. I then showed them the lo-fi prototype and I let them interact with it at the same time as I asked them questions regarding the prototype and the potential use of it. The questions were semistructured, where I had an agenda for the tests to see if the concept of having electronic components as physical tools for creating interactive lo-fi prototypes and to facilitate visualizations of ideas, would be useful to them. I wanted to know how they could benefit from using these types of
tools in their design work. Not all users could easily grasp the concept and said that it was hard to imagine the interactions and how they would work when it only was made out of paper.

**Workshop**

I implemented a workshop session during the user tests where I wanted the user to draw down their own ideas of how they visualized a design tool which they would want to use themselves, or drawing down how to improve the already existing concept which they were testing. The reason for the workshop was to try to get them to move away from only using words and thoughts when describing their ideas and to make them draw down their own ideas instead. This approach wasn’t very successful, because of the lack of enthusiasm and willingness from the users to draw down their own ideas. Only one of the users had an idea which was drawn down. They all had experience of working with prototypes before, but they had all different levels of knowledge in the field, which I saw as beneficial and which gave me a wider range of users and different backgrounds and knowledge.

*Figure 13 An idea from a user tester.*

**6.6.1 Result of user testing 1 & workshop**

**User 1**

The first user whom tested the prototype had some concerns regarding the usefulness of the prototype. User 1 suggested having components and microcontroller pre-programmed with specific purposes. For
example, user 1 said that having a microcontroller that could “feel” if a button was connected in one of the inputs and a led was connected to an output, would make testing of interactions much easier, without the need for writing code. User 1 mentioned a project which whom had created, which could have benefited from using this type of physical tools.

**User 2**
User 2 thought the concept was a bit vague and couldn't see the functionality with the components very clearly. If the purpose of the concept was to create a new platform for visualizing ideas, then the new platform would have to replace all the already existing functions of other platforms. Therefore user 2 thought it would be better as a complement to an already existing platform, such as the arduino. User 2 had ideas about how to make the prototype user friendly, which included different colors which would separate output from input, which would make them easier to distinguish from one another.

**User 3**
I presented my concept and the lo-fi prototype poorly when user testing with user 3, which resulted in user 3 not fully understanding the idea behind the prototype. But because of user 3's wide range of knowledge in the field of physical prototyping, I could still receive useful inputs regarding how users might perceive the components. User 3 said that clearly visualize each component with a symbol of what it represents would be required. For example, a led should have a clear and easy to understand symbol of a led, with a possible text describing it. User 3 also mentioned the potential use of the components as replacements if user 3 didn't have all the components needed for testing and building a prototype.

**User 4**
The feedback from user 4 was mainly regarding the usefulness for the first time users of electronics and prototype building. Where having components would make it easier to understand and learn how to create prototypes and do programming.

**User 5**
The professional designer had a bit different view of the concept than the other users. It was more regarding the usefulness for companies using this tools, rather than how to improve and change the existing concept. The designer mentioned the time you can save when testing new concepts and prototypes with this type of platform. The fact that having many components, which can be used for different things was seen upon as a good possibility to simply build and try new ideas rapidly.

The overall impression I received from the user tests was that the concept was perceived as a possible usable tool for creating lo-fi prototypes, but that it had flaws and unclear purposes which needed to be
addressed. And that it should rather be used as additions to already existing physical tools for visualization, than being a separated platform.

**Design principles for prototype 2**

- Make the modules user friendly and easy to distinguish from input and output.
- Clearly state what each module does, symbols or text would help simplify the usage.
- Make the modules simple enough so that anyone from beginners to professionals should be able to use them.
- Different electronic components should be able to be used for rapid prototyping ideas.

### 6.7 User testing 2

Before the second round of testing I improved the design concept by taking in account the result from the first user test into the new prototype. I decided to create a mid-fi prototype with electronics inside of them, which made them little interactive and more usable. The purpose of this test was to see and understand how the users interacted with the components, how they managed to accomplish the goal of the test. How they thought the design should be and how the visualization of the different electronics components should be created. Just as in the previous test I conducted this test with four interaction design students and the same design professional. Some had participated in the previous user test and for some it was the first user test they participated in.
I decided to create two smaller interactions for the users to try, in the first interaction they needed to connect one input, a button and one output, a led to the microcontroller. As the first user test showed, some of the users thought it was hard to grasp the concept of how to use the different prototyping modules. As I have stated before, this interaction resemble the ones found in TinkerKit and littleBits, where you connect the different components together without soldering. I wanted to see if the improvement I implemented from the first user tests made any difference, in terms of usefulness, easy to distinguish and easy to interact with. The test started with the users interacting with the prototypes without me saying anything about how it works or how the interaction is. I asked them to first talk aloud of what they thought of the first impression they had. If it was simple to understand, how they thought the interaction was intended to work. All users could understand the first interaction and was able to complete it without any problems. The second part was to control an animation which, if done right would turn the led on. This was used by connecting a potentiometer and controlling a processing sketch. The users liked the idea of not having to build circuits just for rapidly testing out ideas and concepts. Having prototyping modules was seen as something useful for beginners and people wanting to learn about electronics. As this thesis strives to research how to design and create a prototyping module aimed for interaction designers, I wanted to know how the prototype could be improved in such way that it would be useful for them in their work and studies. I used semistructured questions

**Figure 14 Second prototype being tested with a user**
which I asked throughout the user test, where I after the interactions asked questions which I came up with during the discussion.

6.7.1 Result of user testing 2

Color code: Almost all users thought the usage of color for separating the different components from each other into different categories was something they considered very important and useful. The color should not be too intense as it might affect paper-prototypes negatively. They thought white would be a good choice, because it is a neutral color, another idea was to use light yellow.

Symbols, icons & text: As a simple way to show what the different components was and what it could be used for, was the idea of universal symbols and icons representing the components was given. A led could best be represented by a light bulb, a potentiometer could be represented as a stereo controller. An interesting input was to add text on the backside of the components to describe what they could be used for or what electronics components necessary for building them yourselves.

Wires: The wiring of the prototypes was intentionally bad, to get a reaction of how the user would want it to be instead. A big problem which all the users had experienced when prototyping was the fact that wiring was hard when a lot of electronics was used and often the wires didn't connect well enough on the breadboards which made building and error searching tedious. They wanted something simpler which would help the wires stay in their intended positions and not lost their connections easily.

Attachable: When building lo-fi prototypes the users thought it sometimes was hard and that it took too long time to get the electronics in place and make them stick. Often glue or tape was used to make the components stick to different surfaces. Therefore having components which easily could be attached to different surfaces was popular.

Flexible module: The users thought that to make the prototyping module more usable and user friendly for interaction designers, they suggested a prototyping module which could work for many different electronics components and not be restricted to only one component and one purpose. They meant that they didn’t want to invest in pre-assembled modules when they already had working electronics components which they could use together with the prototyping module.
**Replacements:** An aspect most of the users agreed on was that having pre-assembled components could work well as replacements if the users didn't have the right components to build them themselves.

**Design principles for prototype 3**

- Being able to differentiate output from input using different colors.
- Adding symbols for easily showing where the different electronics components could be used on the prototyping module.
- Re-design the concept so that several electronics components can be used on the same prototyping module.

I didn’t consider making the module attachable, nor implement a design solution for the wires due to simplicity reasons for the thesis.

**6.8 User testing 3**

For the third and last prototype I designed the prototype with more connections for different electronics components and added symbols and different coloring for distinguish them from input and output. The user tests were this time as well conducted with five different testers, four students and the design professional. I started with explaining what the test was going to be about, I then let the users interact with the prototype and think aloud what they thought of the new design and if the symbols and text were helpful to them. After they had given feedback of the visual aspects of the design I asked them to interact with the prototype by letting them connect different components onto the prototype; LDR, Potentiometer and a button which was used for turning a led on and off. I wanted to get feedback and to understand how they felt about interacting this way, compared with the second prototype where all components were static and already assembled. I followed up with semistructured questions about how to improve the prototype, which electronics they would want to use together with the prototyping module. What they thoughts were regarding the new design of the prototyping module, which was a result of the last user test, where some users mentioned that they rather wanted a module compatible with more electronics than just one.
Figure 15 Third prototype being tested with a button connected

6.8.1 Result of user testing 3

Improvement: The users thought that it was a simple way of connecting the different electronics onto the prototype for rapid testing an interaction. Some mentioned that they thought it was a good improvement from the second prototype.

Position the symbols: The positions of the symbols on the prototype for representing where the different components would be connected weren’t much liked. When connecting the button, the symbol disappeared under the button, and the users rather wanted the symbols to be seen at all time.

Separate the connections: When asking how they thought the placement of the different connections were located, most of them liked it, but they thought it was a bit confusing with all the connections and symbols and rather wanted the different connections for different electronics components to be divided into separated squares for a simpler visual layout.
5V, PIN & GND: Some of the users thought it was hard to know which contact of the electronics components should be connected to which connection on the prototype, for example; if there were three connections, 5V, PIN and GND, it was hard for the users to know which wire or connection would go where. Therefore they would like to have visual feedback where there would be text saying 5V, PIN and GND to differentiate the different connections from one another.

This was also seen as a good reference as to knowing where on the microcontroller they should connect the different wires from the prototype.

Digital vs. Analog: An idea that arose from one of the users was to also differentiate analog input/output from digital input/output.

Design principles for the final design

- Change the position of the symbols so that they are visible even when electronics components are connected.
- Divide the different connections form one another into separate parts, for a simpler visual layout.
- Add text of 5V, PIN and GND to simplify for the user where to connect the contacts of the electronics components. This will also work as a reference for the user, to know which wire goes where on the microcontroller.

6.9 The final design

The final design resulted in an illustration of how the prototype could look like in a potential next step of the iteration processes of the design. Before deciding how the final design should look like I also looked through the first and second design stages to collect the most valuable results and tips generated from the user tests. The feedback I had received from the user tests was that the new design was appreciated which made the interaction of more components flexible and more user friendly than the original design. As figure 16 shows, I changed the position of the icons so that they at all times will be seen, regardless of having electronics components in place. The different connections for the different electronics have been divided into their own sections to make it easier to know where to connect. As many users thought it was hard to know where to connect the electronics, they wanted to see some kind of visual feedback on where to connect. Therefore I implemented 5V, PIN and GND text to all different connections for simplifying for the users.
7. Discussion

In this thesis I have tried to research how to improve physical prototyping modules for facilitating the ease of testing ideas with simple technology for interaction designers in an early design stage. I wanted to understand what the users thought of when building prototypes for visualizing ideas, what worked good and what worked bad for them and from their point of view try to design and implement a better design solution for them to use. Through the research I conducted I could find problems with using prototyping modules and building prototypes. With the methods used in this thesis I tried to find solutions which could simplify for the interaction designer’s to faster and earlier on test and build their ideas and interactions.

In this part of the thesis I will discuss the result gained, methods used, the research conducted and the theory I found and I will also give critic on what went well and what didn’t go well.

I was inspired by prototyping platforms such as Arduino, Makey Makey, TinkerKit and littleBits. Which have opened up a new world for people which before didn’t have any possibility of creating and building their own prototypes from their own ideas. People without any previous experience can quite easily start creating by themselves. The theory of tangible user interfaces has given me an understanding of what problems exist and why they exist. In my design process I have found that users want to be able to choose what to use and be flexible to create according to their own mind and not be restricted by any technology. As Gandy et al. (2009) explain a big problem for technology and
creating physical products is the high barrier of knowledge of electronics and programming which people have to cross. By simplifying for people to build with electronics I wanted to design a solution which at the same time as it give them the possibility to fast try out their ideas and interactions; it also let them be flexible and creative.

Arduino is a prototyping platform which has helped revolutionize the way we perceive technology and how we are changing the way we use it, together with the maker’s movement (Tanenbaum et al 2013). What I found in my research was that users thought the platform was a good and useful tool, which helped them accomplish their goals and ideas, but that it also had some flaws the users did not like. In my design principles I gathered what I wanted to improve or implement from the user tests into the next prototype of the design process. I saw problems regarding connecting electronics and other components together, wiring to the Arduino, troubleshooting and being able to faster test out ideas.

I believe designing for many users whom have different points of view is hard which increases the risk of failing with your design. As my research has shown, limit myself to only interaction designers and not spreading out to a wider range of professions might have helped me in the design process of creating the design solution. This is according to Cooper (2004) a good aspect, which if I had included more users there would have been an increased risk of the design failing due to it not achieving the expectations of the users. But rather becoming a mismatch of many thoughts and expectations from different design disciplines and users.

Conducting interviews helped me get more insight and better understanding of how interaction designers work with technology and by asking questions I received information which I believe wouldn’t have been possible to collect without interacting and talking to the users about what they thoughts were on the subject and to give them the possibility to freely speak their minds when someone was listening. I think this helped me go through the different stages of the design process, which is what Ejvegård has shown in his research (2003), that when letting the interviewee answer and talk as much as one want you can gain a lot of valuable information and knowledge just by letting them speak.

From my researched I found that making technology simple and easy to use was an important result, which would allow more people to interact with the technology. Creating the right expectations for the users, regarding what state the prototype is in was considered helpful for the users. From the results I could later create three different concepts. This helped me get a better idea of what would be the better start of my thesis. The concept helped me sketch out my first lo-fi prototype which I used in my first user tests. The reason why I would include the concept development was as Buxton (2007: 139)
argues was because sketching is a great tool for generating many ideas rapidly early on in the design stage.

I created in total three prototypes, one lo-fi and two mid-fi prototypes. The first one was created for presenting the concept and letting the user testers give their thoughts of the concept. The two mid-fi:s was created based on the feedback I had received from the earlier user tests and aimed toward the interaction and what the users thought about it. Using prototypes has its benefits, as we are humans we perceive our world around us with our senses, where touching and interacting with physical objects (Patten & Ishii 2000) helps us understand more about an object and experiencing a prototype makes it easier to understand an idea instead of having it described in words (Zaki Warfel 2009). What I found from conducting the user tests was that explaining the state and characteristics of the prototypes, such as; lo-fi and mid-fi didn’t make it easier for the users to understand. I believe that using a terminology specifically used by designers and engineers in the context of explaining for users without any insight in the process or project can be misleading and confusing for the user. This also states Houde and Hill in their paper. People have different experience with technology and terminology; therefore can one prototype be a lo-fi or a mid-fi depending on the user (1997).

My ambition with conducting the user tests was to get reactions on the project, feedback and criticism from the users. I believe that I did not succeed completely when conducting the user tests. I failed in explaining the concept and making them grasp the idea completely. I think if I had gone through the questions with a test person before conducting the tests would have helped me figure out how to present my concept in another way. The way I tried to conduct the workshop didn’t work as I had expected, I believe implementing the workshop together with the user test made the users insecure and was reluctant of participating. Even though, I believe conducting these tests did give me enough feedback and criticism to be able to move my thesis forward to the final design solution.
8. Conclusion

The question I am going to answer in this thesis is “How can prototyping tools be re-designed to facilitate the ease of building and testing ideas early on during a design process for interaction designers?”, my work has enabled me to narrow down aspects which should be considered when re-designing prototyping tools for interaction designers.

When re-designing prototyping tools aimed for interaction designers I found that the best way to do so is to adapt the technology to the interaction designers, with this I mean; removing unnecessary parts and scaling down the prototyping tool to only contain the essentials for the interaction designers and visually make it easy for them to interact with the prototyping tool. As interaction designers are not engineers, avoiding unnecessary wiring and building will allow them to concentrate on visualizing their ideas instead of worrying about connecting wires and troubleshooting.

When designing for interaction designers you should design to enable the users to easily be creative and eliminate obstacles which can harm their creative design process. As technology can easily become tedious it’s important to know its limitations and design for minimizing errors which can occur. It is also necessary to give the users the ability to choose themselves how to use the object and being flexible to match their different expectations and not force them to use static technology.

I found that when designing for an already existing platform or object it is important to listen and take into consideration what the users demands and wish for. Designing the object to be functional together with other platforms which the users already are using is crucial. Forcing them to learn new interfaces can only mean that the design has failed with its purpose.

In my thesis I have conducted research to create a user friendly and flexible physical prototyping module to facilitate for interaction designers to rapidly try out their ideas and concepts with the help of simple technology early on in a design process. The prototyping module enables the interaction designers to choose themselves what they want to create and build without having to build circuits or do soldering. There needs to be a balance between being enough flexible for the user to want to use, with little restrictions and at the same time it should be user friendly and simple to interact with.
9. References

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Appendix 1

Questions for the Interview translated from Swedish to English.

How does a regular design process look like for you?

What methods are being used for generating ideas and concepts?

Which kinds of prototypes do you use? What purpose does the prototypes have?

Have you ever felt that you can’t explain an idea and not being able to visualize it?

Is there anything missing when visualizing ideas?

Would a visualization tool affect your design process?
Appendix 2

Questions written down for the user tests translated from Swedish to English, unstructured questions which were thought up during the tests were not written down.

What is your first thought?

How can the prototype be improved to suit your needs?

What is bad, what is good?

Is there anything you would like to see in the prototype which is missing?

Any thoughts regarding, the concept, form, color, size, modules?
Appendix 3

Questions to TinkerKit!

Where did the idea of tinkerkit come from? Did you see a demand of these types of tools that wasn't on the market?

When designing and developing the concept, where were any users involved in the design process? If not, why?

Have you gotten any responses back from the users about the products? What does the users like about it? What don't they like?

Tinkerkit facilitates the ease of learning, building and creating prototypes without having to use a soldering iron, but are there any pre-programmed code which can enable the users to just plug and play, without having to type code?

What does the tinkerkit team themselves think needs to be improved or changed to better work for the different users?