Magic Tree - Development of a technology mediating multi-sensory musical instrument

CERTEC | DEPARTMENT OF DESIGN SCIENCES
FACULTY OF ENGINEERING | LUND UNIVERSITY

HERTA STORLIND | MASTER THESIS 2023

Magic Tree - Development of a technology mediating multi-sensory musical instrument

Herta Storlind

Development of a technology mediating multi-sensory musical instrument

Published by
Department of Design Sciences
Faculty of Engineering LTH, Lund University
P.O. Box 118, SE-221 00 Lund, Sweden

Subject: Technical Design (MMKM10)
Division: Certec, Division of Rehabilitation Engineering Research
Supervisor: Charlotte Magnusson
Co-supervisor: Héctor Caltenco
Examiner: Per Kristav

Abstract

This thesis is part of the MISK-project, Musik, Interaktiv design, Sinnesstimulering och Kvalitet (Music, Interactive design, Sensory stimulation and Quality). The MISK-project is a collaborative project between Certec at LTH, Furuboda Folkhögskola and Eldorado Resurscenter, developing musical instruments for children and young adults with mental and physical disabilities. The goal of the thesis is to construct a new type of music instrument that is compatible with the music software developed in the MISK-project, and that stimulates multiple of the user's senses when being played.

During the thesis project, the scope was focused on building an instrument for an upcoming exhibition at Världskulturmuseet, where the MISK-project will be exhibiting. The instrument is built to look like a tree branch, that the user can play on by touching the lights hanging down from it, fitting into the theme of a magical forest, and is named The Magic Tree.

The instrument is constructed using an Arduino, capacitive touch sensors, and fibre optics, to create the sensation of the user playing on the lights hanging from the branch. The Magic Tree emits light through the fibre optics corresponding to where the user is touching it. The branch plays music by sending messages over Wi-Fi to a computer running the MISK music software that interprets the signals and sends out music.

Keywords: multi-sensory, musical instrument, capacitive sensing, Arduino, multifunctional disabilities

Sammanfattning

Det här examensarbetet är del av MISK-projektet, Musik, Interaktiv design, Sinnesstimulering och Kvalitet. MISK-projektet är ett samarbetsprojekt mellan Certec vid LTH, Furuboda Folkhögskola och Eldorado Resurscenter, som utvecklar musikinstrument för barn och unga vuxna med mentala och fysiska funktionsnedsättningar. Målet för examensarbetet är att konstruera ett nytt typ av musikinstrument som är kompatibelt med musikprogramvaran utvecklad i MISK-projektet, och som stimulerar flera av användarens sinnen när det spelas på.

Under examensarbetes gång inriktades projektet mot att bygga ett instrument för en framtida utställning på Världskulturmuseet där MISK-projektet ska delta i utställningen. Instrumentet är byggt för att se ut som en trädgren med hängande ljustrådar som användaren kan spela på genom att röra vid trådarna, och för att passa in i temat magisk skog.

Instrumentet är konstruerat av en Arduino, kapacitiva avkänningssensorer och fiberoptiska trådar som hänger från en trädgren, för att skapa känslan av att användaren spelar på fiberoptiken. Trädgrenen avger ljus motsvarande där användaren rör den. Trädgrenen spelar musik genom att sända meddelande över Wi-Fi till en dator som kör MISK-musikprogrammet, som tolkar signalerna och spelar musiken.

Nyckelord: multi-sensorisk, musikinstrument, kapacitiv avkänning, Arduino, flerfunktionsnedsättning

Acknowledgments

Although I wrote this thesis alone, I have people around me to thank that I managed to finish it. I would like to thank my supervisors Charlotte Magnusson and Héctor Caltenco, for their time, ideas, and hours of patient troubleshooting. Thanks to everyone in the MISK project for the jam sessions and inspiring me with the important work that you do. Thanks to my friends and family for your support, and to my boyfriend for all the food and love.

Lund, August 2023

Herta Storlind

Table of contents

1 Background

1.1 The MISK-Project

This thesis is part of the MISK-project, which stands for *Musik, Interaktiv design, Sinnesstimulering och Kvalitet*, a collaboration between Certec, Eldorado, a center for activity, knowledge, and culture in Gothenburg, and Furuboda Folkhögskola. MISK is a three-year project that aims to develop novel multi-sensory musical instruments, that are possible to customize to the current user and their abilities, disabilities, and personal preferences. The project focuses on building instruments that make it possible people with profound communicational, intellectual, and physical disabilities to express themselves musically and participate in music playing sessions (MISK Project, 2023).

All MISK instruments are stimulating the user’s hearing, by playing sounds and synthesized music, but the MISK-project is also exploring alternative ways to interact with an instrument and receive feedback that traditional music instruments do not normally give.

During the writing of this thesis, it was decided that the MISK-project will have an exhibition at Världskulturmuseet, The World Culture Museum, in Gothenburg, starting fall 2024. The scope of the thesis was adjusted to fit into the development of this exhibition, focusing on developing an instrument that would fit into the selected theme, a magical interactive forest, with multiple instruments collected in a single room.

To fit into the exhibition, the instrument should invite the user to interact with it autonomously, without instructions and rules. The instrument should by itself inspire the user to play on it, and the purpose of it is to inspire the user(s) to make music, alone, or in a group. It is important that the instrument provides clear feedback so that the person that is playing on it gets the feeling of being in control, and that multiple senses are stimulated when playing. The instrument should also be customizable to fit the user’s preferences. The instrument should be built with components that are easily accessible and that can be bought at a low cost.

1.2 Scientific Purpose and Issues

The purpose of the MISK-project, and of this thesis, is increased knowledge about how musical instruments can and should be designed to work for people with multi-functional disabilities within the scope of the MISK-project. Scientific issues to be answered in this project are:

- How can a musical instrument compatible with MISK be designed?
    - What sensors and materials can be used?
    - How should the interaction work?
    - How can the instrument be built to work in an exhibition environment for children, together with other MISK-instruments?

2 Theory

2.1 Target group

The primary users in this design process are participants in music therapy sessions at Eldorado and Furuboda Folkhögskola. Participants in these sessions are children and young adults, with moderate to severe intellectual and physical disabilities. The secondary users are the music pedagogues that set up, plan, and use the instruments in their sessions. The caretakers and the closest relatives to the disabled children can also be considered secondary users, due to their close contact with and responsibility for the children.

2.2 Disabilities

Physical and intellectual disabilities can affect anyone. They can be temporary or permanent and affects a person’s life in many ways. While every person is unique, in the Convention on the Rights of Persons with Disabilities, the United Nations (UN General assembly, 2007) are defining disability as:

“long-term physical, mental, intellectual or sensory impairments which in interaction with various barriers may hinder [a person's] full and effective participation in society on an equal basis with others.”

2.2.1 **Physical disabilities**

A physical disability is a substantial and long-term condition affecting a part of a person’s body that impairs and limits their physical functioning, mobility, stamina, or dexterity (Carehome, 2023). A person can have congenial physical disabilities, meaning they have had the condition since birth, or acquire a physical disability due to accidents, brain injuries, infections or other reasons.

2.2.2 **Intellectual disabilities**

Intellectual disability is an ambiguous term, and the meaning varies in different cultures and during different times. It can be considered a personal trait, but also something that arises in the interplay between the design of the environment and personal traits. However, it does in all cases involve difficulties taking in and process information, to build knowledge, and to apply knowledge. Intellectual disability is determined based on three criteria (Södermalm, 2019):

- IQ under 70.
- Reduced adaptive ability to function in everyday life.
- Causes occurred before 16 years of age.

2.2.3 **Multiple disabilities**

Multiple disabilities is not a diagnosis on its own, but as the term implies, a combination of multiple disabilities. It is often consisting of a combination of severe physical, cognitive, and visual/audial impairment. It is also common to have other medical diagnoses such as epilepsy, breathing difficulties, and a compromised immune system. Multiple disabilities tend to interact and affect each other, often leading to the resulting impairment being greater than the sum of the individual impairments.

A person with multifunctional impairments often needs support from relatives and/or assistants in virtually all aspects of their life (Södermalm, 2019). Most users participating in the MISK project are persons with multiple disabilities.

2.3 Designing for persons with disabilities

2.3.1 **Understanding and communicating with the user**

Most of the users in the MISK-project do not have the ability to communicate verbally, and the interaction with the users is therefore very reliable on observations, physical expressions and the communication between the user and their caretaker. Often, the caretaker has learned to read more subtle expressions from the user and can help communicate the user’s needs. When meeting the users in this project it is very important to adapt to this way of communicating, and it requires more attentiveness to small changes in facial and body expressions, and good communication with the user’s caretaker.

2.3.2 **The pedagogues**

The music pedagogues in this project have worked with the user group for many years and have gained a lot of experience working with them in many contexts, especially musically. Their knowledge of the user group and understanding of music pedagogics is an important source of information in the MISK-project. They are also the ones that will be using the MISK-program and instruments in their work life, and it is very important to include them in the design process, which is being done in the MISK-project in general and in this thesis.

2.4 Universal design

Activity limitations and participation restrictions for people with cognitive impairment can be reduced significantly through the design of systems and the built environment (ISO 21891-1:2020, 2020). *Universal design* can be described as designing for as big part of the population as possible, without special customization. In universal design, it is being considered that people are different and have different abilities, and that these vary over time and with different situations. In 1997, the Center for Universal Design at North Carolina State University developed seven principles for universal design, with the purpose to "be applied to evaluate existing designs, guide the design process and educate both designers and consumers about the characteristics of more usable products and environments". The seven principles are:

1. **Equitable Use**

   The design is useful and marketable to people with diverse abilities.

2. **Flexibility in Use**

   The design accommodates a wide range of individual preferences and abilities.

3. **Simple and Intuitive Use**

   Use of the design is easy to understand, regardless of the user's experience.

4. **Perceptible Information**

   The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.

5. **Tolerance for Error**

   The design minimizes hazards and the adverse consequences of accidental or unintended actions.

6. **Low Physical Effort**

   The design can be used efficiently and comfortably and with a minimum of fatigue.

7. **Size and Space for Approach and Use**

   Appropriate size and space is provided for approach, reach, manipulation, and use regardless of user's body size, or mobility.

Activity limitations and participation restrictions for people with cognitive impairment can be reduced significantly through the design of systems and the built environment (ISO 21891-1:2020, 2020). When continuously following these principles through the process of designing a product, the result will be adapted to as many users as possible, including persons with disabilities. They will be used as benchmarks when developing evaluating the musical instrument in this thesis.

2.5 Therapy types

2.5.1 Snoezelen

There are multiple types of therapy and pedagogic techniques for stimulating the human senses. A previous related project, the SID-project, was focusing on the *Snoezelen-method*. The Snoezelen method was founded by two Dutch therapists, Jan Hulsegge and Ad Verheul. Their goal was to increase enjoyment and sensory experience for those with intellectual disabilities. The term Snoezelen contracts two Dutch verbs: snuffelen (to sniff/seek) and doezelen (to doze/relax). This duality indicates a key trait, as Snoezelen promotes a match of "stimuli" and "arousal" that enables the participant to find the calmness, or the impetus needed to engage in the world (Snoezelen Website, 2023).

2.5.2 Music pedagogics

Music pedagogics study all forms of musical learning and is a cross-scientific field of study that use theories and methods from pedagogics, psychology, philosophy, and music science (Göteborgs Universitet, 2023). Music pedagogics relies on music's ability to create connections, communication, and motivation. Eldorado Resurscenter and Furuboda Folkhögskola both use music pedagogics to create experiences for people who have a hard time using conventional musical instruments.

In a scoping review from 2021, researchers at Department of Special Education, at Stockholm University identified six categories as promising components of musical interaction: the responsivity of the interaction partner, singing songs, structure and predictability in the activities, long-term interventions, technology-mediated and multisensory musical activities, and a therapeutic alliance between interaction partners.

Musical interaction provides a potentially important means of communication for people with severe multifunctional disabilities: “When meeting a speechless client, the music therapist has the tools to promote communicative musicality, thus enabling a person to give their meaning a sound, and to sense that it has been received” (Johnels et al., 2021).

2.6 Tangible interaction

Tangible interfaces use sensor-based interaction, where physical objects, such as bricks, balls, and cubes, are coupled with digital representations. When a person manipulates the physical object(s), it is detected by a computer system via the sensing mechanism embedded in the physical object, causing a digital effect to occur, such as a sound, animation, or vibration. (Sharp et al., 2019). An important part of playing a musical instrument is the tangible interaction. An instrument responds to the user’s interaction by sounding, but also by vibrating. The sensation of the instrument vibrating tells the user about the current state of the instrument. In the MISK-project, the instruments are connected to the musical software and the sound is produces digitally, and the natural vibration of the instrument body is lost. To make the user understand the connection between their input and the output sound, the instrument needs to provide another type of feedback. Techniques used in Snoezelen and in existing prototypes of the MISK-project are visual animations, LED-lights, and vibrations. In this project I will explore which types of feedback will work together within the project’s scope.

2.7 Software elements

User interaction is the focus of this project. The goal is to construct a product that is intuitive and inspiring for the user to interact and play with, and that is easily customizable for the pedagogue, through the MISK-application. From the application to Allmänna Arvsfonden:

“Today there is access to powerful but cheap and easily accessible Open-Source technology to put together and customize that has not existed before. The MISK-project wants to use this technology to develop musical instrument that are possible to make user customizable and build, regardless of prior knowledge or socio-economic background."

Two examples of such technology is the Max software and the Arduino platform, described in sections 2.7.1 and 2.7.2.

2.7.1 The MISK-application in Max

The MISK-application is built in Max, a programming language suitable for interactive software, focusing on sound and image processing (Cycling 74, 2023). The programming is visual, and the workspace consists of an infinite space where functions are placed and connected via cords, like an analogue sound system. The MISK-application is built by the MISK-project and my application will communicate with this software.

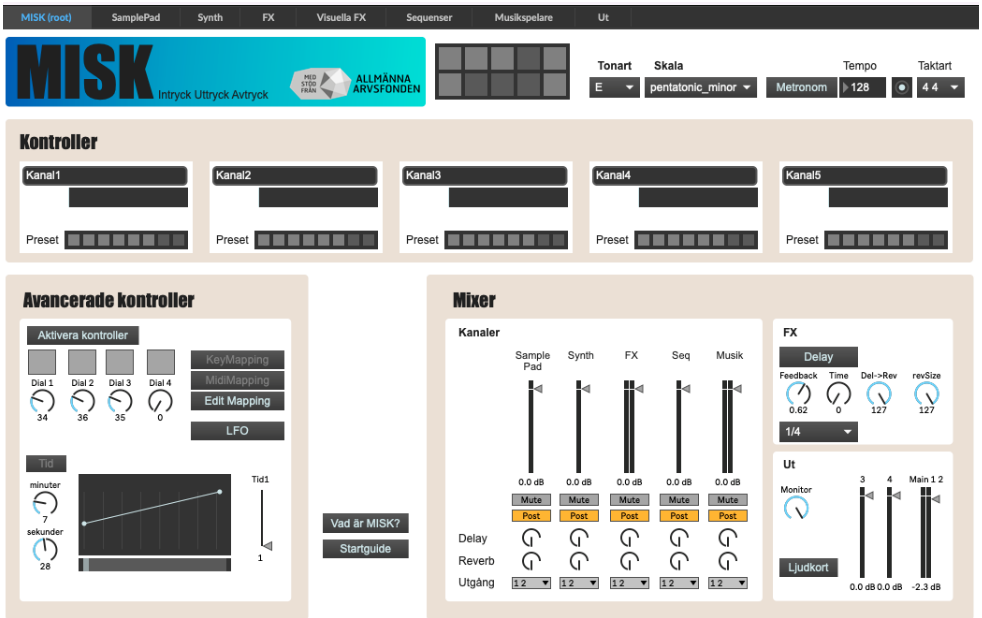


Figure 1 – Start page of the MISK-program (MISK, 2023)

2.7.2 Arduino

The prototype is built using Arduino, an open-source electronics platform based on easy-to-use hardware and software. It is intended for anyone making interactive projects (Arduino, 2023). Arduino is a fast and simple way to make interactive design prototypes and products and has been used in the previous musical instruments within the MISK-project. Arduino components are relatively cheap and easily available, making it an accessible way of building interactive electronic devices. A few of the instruments built in the SID-project and the MISK-project are built with Arduinos and therefore I have chosen to also work Arduino in my project. The Arduino IDE, integrated development environment, contains pre-written code, *libraries*, that can be used and combined to make new projects.

2.7.3 **OSC-protocol**

Open Sound Control (OSC) is a protocol, a composition of data types, for networking sound synthesizers, computers, and other multimedia devices for purposes such as musical performances and MIDI Show Control (MSC). MSC is an open, industry-wide international communications protocol through which all types of show devices can communicate link together and operate multiple entertainment control systems in a coordinated manner. To communicate with the MISK-application, the Arduino prototype will send OSC-messages over the local Wi-Fi network. This is to make the instrument work without being connected physically to a computer, and to ensure that the communication is fast enough. This requires the use of a Wi-Fi compatible Arduino in this project.

2.8 Hardware elements

2.8.1 **Contact microphones**

One type of sensor that was considered for the instrument is a piezoelectric microphone, also called contact microphone. These microphones use the Piezoelectric effect, that certain materials generate measurable potential difference when made to expand or shrink. The opposite is also true: applying an electric field to a piezoelectric material leads to the addition or removal of electrons in the material and causes the material to deform and thereby generate a small physical force. This means the contact microphone can also be used as a contact speaker.

The contact microphone can be used for picking up sound not only from traditional instruments, but from touching different materials. They're sturdy, cheap, and therefore an interesting sensor for this instrument build.

2.8.2 **Electret microphones**

Electret microphones are the most common microphones today, used in both studio microphones and cell phones. (Open Music Labs, 2023). They are condenser microphones, meaning they use condensers, also called capacitors, to pick up sound signals. A thin membrane of electret material is closely spaced to a metal receiver plate, with an amplifier attached. The electret material can hold a fixed electric charge, which makes it differ from a conventional condenser microphone that needs power (i.e. phantom power) to keep its charge. When air vibrates against the membrane, it changes the distance to the amplifier plate, resulting in a voltage difference. When amplifying these signals, the output signal is a sound wave.

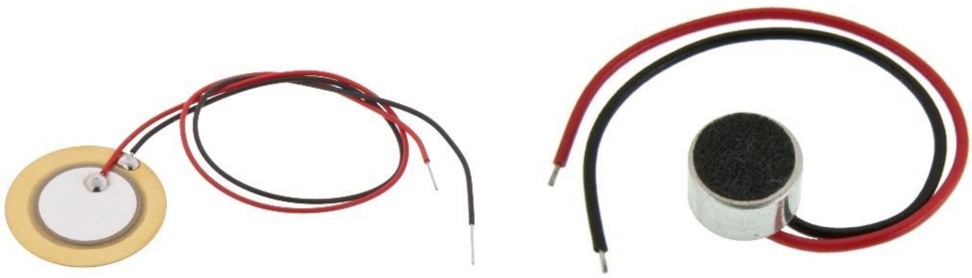
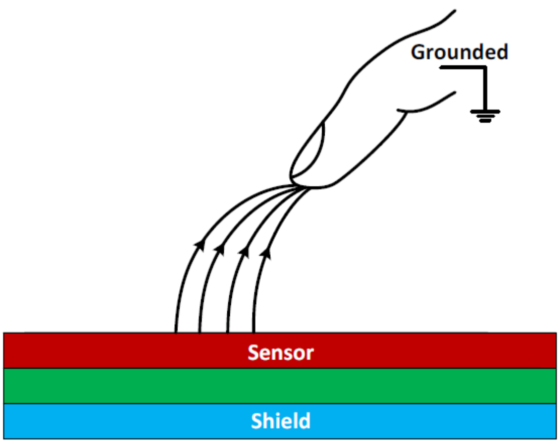


Figure 2 – Left: Contact microphone. Right: Electret microphone (Electrokit, 2023)

2.8.3 **Capacitive sensing**

Capacitance is the ability of a capacitor to store an electric charge. Capacitive sensing, or CapSense, is a technology based on capacitive coupling that takes the capacitance produced by the human body as the input A basic capacitive sensor is anything conducting, e. g. a metal, that detects anything that is conductive or that has a dielectric constant different from air. (Texas Instruments, 2021).

Figure 3 - Illustration of capacitive sensing (Texas Instruments, 2021)



2.8.4 **Fibre optics**

Fibre optics, or optical fibres, are flexible, transparent hair-thin glass or plastic fibres clad in a buffering reflecting material. The buffering material traps the light in the core up to a certain angle and allows light to travel along the core. Glass fibre is flexible, strong and has lower loss than metal wires, and is immune to electromagnetic interference and safe to touch. These properties make it a suitable material for interactive lighting solutions. The fibre optics are come in different diameters and can be manipulated to transmit different amounts of light along the fibre. To pick up signals from the sensors, convert them into OSC-messages and send them to the computer, a WeMos D1 Wi-Fi ESP8266 board is used. The WeMos board is compatible with Arduino libraries and has a hardware resembling Arduino Uno Wi-Fi. The WeMos board has capacity to communicate over Wi-Fi. (Instructables, 2020).

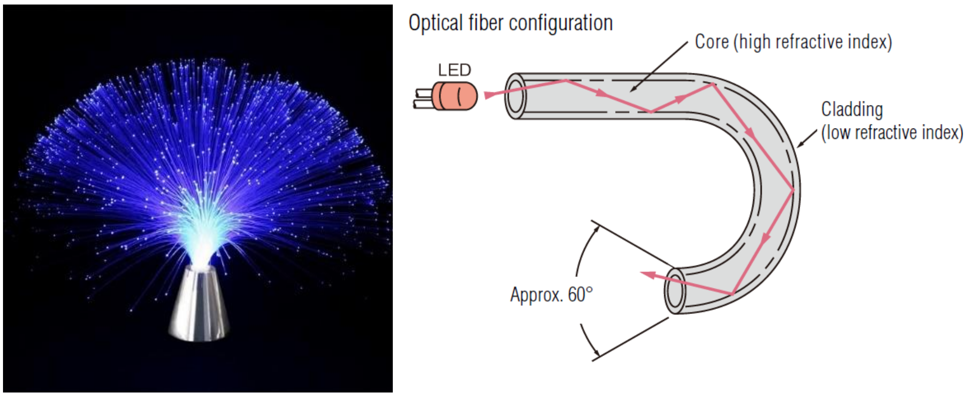
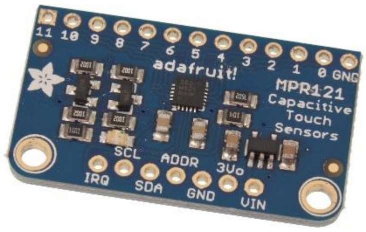


Figure 4 – Left : Fibre optic lamp (Aliexpress, 2023). Right: Fibre optic functionality (Keyence, 2023).

2.8.5 **MPR121 breakout board**

The WeMos board has limited capacity for analogue inputs, such as capacitive sensors. In this project, since we want a variety of notes to play, multiple sensors are needed. For this, we use the MPR121 breakout board, which has the capacity to read up to 12 capacitive sensors and is compatible with Arduino and WeMos. (Electrokit, 2023). In the project, two boards are used, making it possible to add up to 24 individual capacitive sensors, using the Arduino library written for this board.



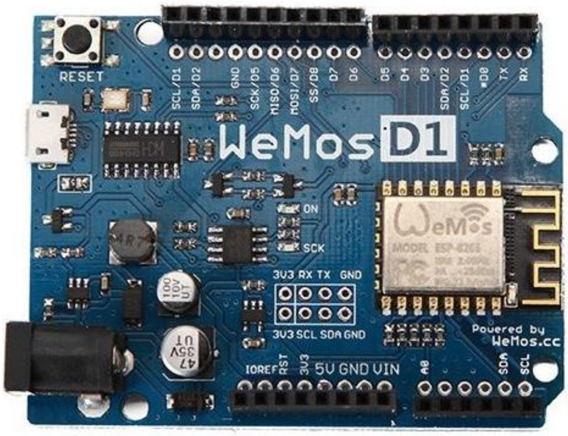


Figure 5 - Left: WeMos D1 R2 Wi-Fi board (Electrofun, 2023). Right: MPR121 Capacitive sensor breakout board (Electrokit, 2023)

3 Design process

3.1 The Double Diamond design process

In this project, the Double Diamond design process model is being followed. Divided into four distinct phases, Discover, Define, Develop and Deliver, it maps the divergent and convergent stages of the design process (Design Council, 2009).

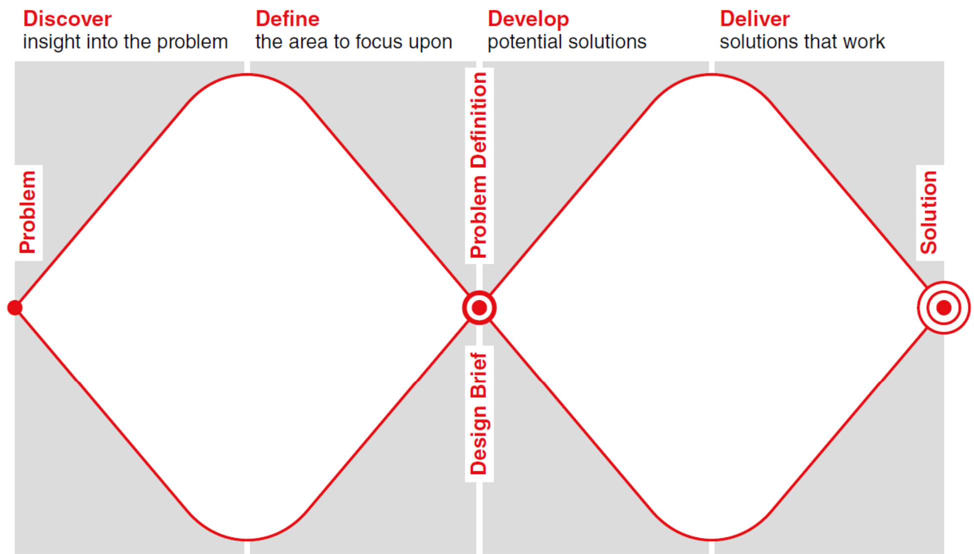


Figure 6 - Illustration of the Double Diamond design process (Sharp et al, 2019)

3.1.1 **Discover**

The *discover* phase marks the beginning of the project. The goal of the first phase of the Double Diamond process is to discover requirements for the product. This includes doing a literature review, user research, brainstorming and market research.

3.1.1.1 Literature review

A literature review is conducted to examine what has previously been published within the chosen topic. The review is done to establish context of the project, to identify research gaps, evaluate methodological approaches and to build a solid theoretical framework for the thesis.

3.1.1.2 Market research

A source of information for the project is looking at what products and data is already on the market. When doing market research, gaps in the market, areas for improvement and innovation and maybe also future trends can be identified (Design Council, 2009).

3.1.1.3 User research

User research is done to identify who the users are, collect data and to gain further understanding about their needs. User research methods can include both quantitative and qualitative data. When working with a user group that is relatively small and diverse, and within a topic that is creative and based on creating an experience, as in this project, finding and gathering relevant quantitative data can be difficult, and it is more common to focus on qualitative research methods, such as interviews and making observations.

3.1.1.4 Observational study

The main method used for doing user research in this project is observational studies. In the user group, the users commonly do not have the ability to speak, read or write, narrowing down suitable types of data collection methods. The figure below describes observational studies.

Direct observation in the field	Understanding context of user activity	Mostly qualitative	Observing gives insights that other techniques don't provide.	Very time-consuming. Huge amounts of data are produced.
Direct observation in a controlled environment	Capturing the detail of what individuals do	Quantitative and qualitative	Can focus on the details of a task without interruption.	Results may have limited use in the normal environment because the conditions were artificial.

Figure 7 - Observational studies (Sharp et al, 2019)

The observational studies carried out in this project are a mix of observations in the field and in a controlled environment. In the workshops, where the observational studies have taken place, the users are participating in musical pedagogics sessions as they normally would, but with new types of instruments set up to test.

When planning and conducting observations, it is important to consider that a lot of information can be collected. If possible, it is useful to carry out observational studies with more than one observer, to enable focus on different parts of the test. It is important to take notes, since valuable information may otherwise be lost. To work in a group, let someone else check your observations list and to make video recordings are strategies to improve the quality of the observational study.

3.1.2 **Define**

The define stage can be considered a filter, where collected data from the discover stage is being reviewed, analysed, and defined into problems and potential solutions are starting to take form. The goal of the design stage is to present a clear definition of the problems, a *design brief*, described in section 3.1.2.1. In this thesis, a list of user needs and responding required or desired functions for the instrument is collected and presented. It is common that the discover and define stages are taking up majority of the time spent in the design process (Design Council, 2009).

3.1.2.1 Design brief

A design brief is an outlining document for a project, including background and scope for the project, expectations and goals, constraints, and budget (Design Shack, 2023). In this thesis, the design brief is not a separate document, but is shortened into a bullet point list summarising the required information for the project.

3.1.3 **Develop**

With a clear design brief created, the development of the product(s) is starting. Solutions and concepts are generated, ranked, combined, and refined, often in an iterative process, through brainstorming and prototyping, beginning with simple, *low-fidelity* prototypes, and later with more complex, *high-fidelity* prototypes. An important part of the development process is testing the prototype, seeing that it fits into the requirements and to make improvement based on user input. The goal of the development phase is to find a concept that fulfils the requirements set up in the *define* stage, and to present a working solution to be further developed in the next step.

3.1.4 **Deliver**

In the deliver phase, the product is being refined to be ready for market release and launched. The products are going through the final testing, approved for market and add-ons such as packaging and branding is developed.

4 Discover

4.1 Project plan

The project runs over 20 weeks, starting with making a project plan, and ending with an oral presentation. To ensure that the process fits within the time frame, a project plan in the form of a Gantt-chart is made:

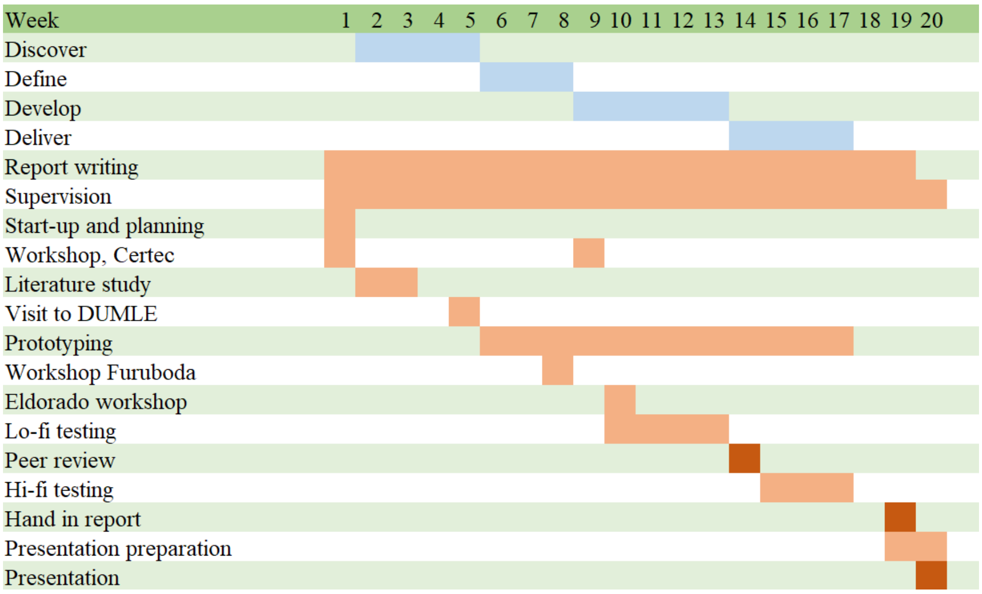


Figure 8 - Gantt chart according to plan

4.2 Scope

The scope of this thesis is formulated by the MISK-project goal:

Develop a new type of technical-mediating and multi-sensory musical instrument, that is adaptable based on the user's resources and interests, i.e., movement abilities, individual ways of communication and sensory and musical preferences.

Additional initial requirements are compatibility with the MISK digital platform being developed in the project, and that constructing the instrument does not require components that are difficult to find or build, to make the instrument easily accessible for everyone.

4.3 Literature review

The literature review in this thesis was done in the first weeks of the project. In the literature review I have mainly focused on reading the dissertation by Henrik Svarrer Larsen done within the SID-project, and the article *Musical interaction with children and young people with severe or profound intellectual and multiple disabilities: a scoping review.* A search for articles on Google Scholar and literature search at Folkbiblioteken Lund. Keywords used were *Snoezelen, Music therapy, Music pedagogics, Multisensory.*

4.4 Market research

4.4.1 **Existing instruments within the MISK-project**

The MISK-project has developed multiple instruments in three different categories: Apps, tangibles, and computer vision.

App: The Face-OSC app is developed for tablet and smart phone use and reads the user's facial expression. By changing the facial expressions, the user can control different elements, both visuals and audio.

Tangibles: The *Magic Curtain* uses a projector to project colours on a screen made of thin fabric and picks up the user's movements by filming the screen with a camera. The *MISK-Pillow* uses pressure sensors to detect the user playing, and projects light where the user has touched it. It allows the user to lay on it, hug it and stand on it.

Computer vision: The *MISK-Moves*-application is a thesis done in parallel with this thesis, that focuses on implementing a machine learning model that recognizes movements in a room. This instrument is played by detecting placements of defined points on the human face and body.

All the instruments in the MISK-project are compatible with the Max software and can be programmed to control visuals and sounds as the user and/or the pedagogue decides.

4.4.2 **Visit to DUMLE**

Du Utvecklas Med Lek, DUMLE, is an idea bank for persons at an early stage of development, at the Habilitering och hjälpmedel (habilitation and aid) at Region Skåne in Lund. DUMLE is a collection of tools and toys with multi-sensory stimulation, where families can come and learn about and get inspiration for toys and sensory stimulating material. DUMLE focuses on equipment that is easily found at home or cheap to buy and easy to build, to make is as available and affordable as possible.

DUMLE has products for all senses, but on my visit, we focused on the equipment that was related to music and vibrations. We tried a vibrating cookie jar, which buzzes when the lid is pressed. The pedagogue at DUMLE explained that many of the children that are visiting with severe autism were often calmed down by the vibrations and liked to use the vibrating cookie jar when simultaneously doing something else. The constant input from the vibrating jar helped the children sense their body and to relax, allowing them to focus on other things. Many of the children enjoys using both the vibrating mat or the vibrating jar and other toys or instruments at once, she explained. After this visit I was inspired to focus on the vibrations in the instrument.

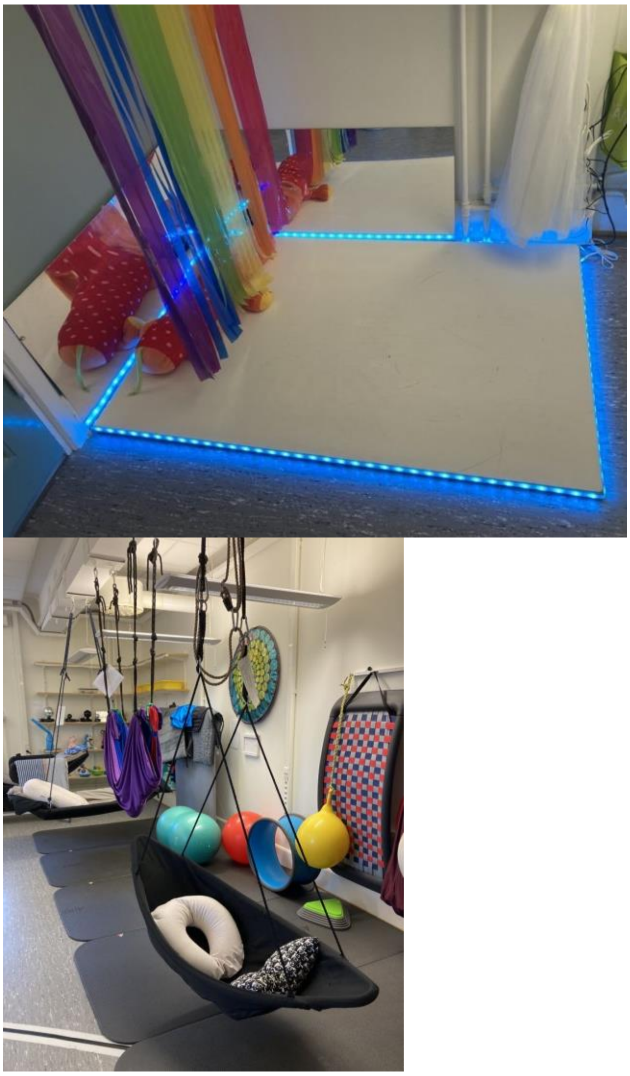


Figure 9 - Pictures from DUMLE. From top left to bottom right: 1: A Cookie jar that vibrates when the lid is pressed. 2: A speaker inside a pillow. 3: A floor with a subwoofer that vibrates 4:. Swings.

4.4.3 **Commercial products**

There are many existing toys and instruments on the market designed for the user group. I have looked at and tried a selection of them.

Musii, MUltiSensory Interactive Inflatable, make inflatables that are illuminated when played, offering visual and tactile sensations (Musii, 2023).

Trigger switches are commonly used for persons with disabilities to enable users to control their environment. They are buttons that come in different sizes and that can be plugged in to for example toys and instruments to start or stop them.

Figure 10 - Left: Trigger switches in different sizes from DUMLE). Right: Musii instrument (Musii, 2023)

Quha Zono is a gyroscopic mouse controller that can be mounted on the head or held in any other way the user chooses. It controls the mouse by rotating and moving it around, and it calibrates itself to detect small or big movements, making it possible for most users to move the mouse. The mouse can be connected to control music in the MISK-program.

EyeHarp is an instrument based on computer vision, more specifically eye tracking, where a camera monitors eye movement. By looking at different notes on a screen, the user can play the instrument (EyeHarp, 2023).

4.5 User research

4.5.1 **Visit to Furuboda**

Together with two pedagogues from the project, I went to visit Furuboda Folkhögskola to meet one of the users in the MISK-project. At this point, I did not have a prototype of the instrument, and the purpose of the visit was to get to know a user, try the MISK-application in action and brainstorm with the pedagogues. We set up the Quha Zono, mentioned in the previous section, for her and were playing together, mixing acoustic and digital instruments with the MISK-application. I took notes of observations and discussion points from the workshop, that I summarised into bullet points. Statements and observations from this visit that I took with me from this visit are the following:

- It is obvious when the user is engaged in the playing, and when not.
- Clear feedback, visual or other, from the software and the possibility to choose a sound that the user likes make the user more engaged and awake
- Many tools and available instruments have a plastic and digital look and feel. This user wished for an instrument that looks more like a "real", analogue instrument.

4.5.2 **Workshop at Eldorado**

Beginning of May, the whole MISK-project met for a workshop at Eldorado in Göteborg. Three rooms were used to test the instruments with different users. I did not have my prototype ready for testing and focused on observing the use of the other instruments. Three sets of users, six persons in total, took part in the testing session. We tested the instruments from section 4.4.1, including some additional contact microphones set up to make noise with water bowls, and two pedagogues held a multi-sensory music journey with two users on a very early development level. It was very inspiring an educational to take part in the workshop.

During the workshop I was observing the users and discussing with the music pedagogues, taking notes of what I observed and what was discussed. A lot of information was collected during the day and I went through my notes and pictures that were taken to narrow down the information to bullet points of the most important observations, arriving at the following statements and observations:

- The possibility of playing together with many people is inspiring and useful.
- The users have different interests and strengths.
- Users are drawn to different materials.
- Clear visual effects make instruments more fun and captivating to play on.

- Looking at existing MISK-prototypes, there is room for exploring new materials and alternative designs.
- Varying the construction material can be a way to increase the tactility of the instrument.

4.5.3 Importance of user customization

During both workshops, it is clearly showing that the users can express their preferences very clearly, sometimes with the help of a caretaker. A user that is not stimulated and engaged in the interaction with the music is quickly zoning out and shows a decline in energy. However, when a user gets to interact with a sound, material, and interaction type that they enjoy, their energy level increases, and they respond very clearly to their surroundings.

Every user is different and has their own preferences which makes it very important that the instrument is easily customizable, making it possible to supply the musician with an instrument that catches their attention and makes the whole experience enjoyable.

4.5.4 Observations and statements

The observations and statements from the two workshops are collected below.

Observations:

- The users have different interests and strengths.
- Clear visual effects help catching and keeping the user’s interest.
- Instant audial feedback clear patterns in music help catching and keeping the user’s interest.
- It is obvious when the user is engaged in the playing, and when not.
- The possibility to choose a sound that the user likes make the user more engaged and awake.
- Users are drawn to different materials.
-

Statements:

- One user is requesting a “real” looking instrument.
- There is room for exploring new materials and constructions t

4.5.5 The exhibition at Världskulturmuseet

The MISK-project will be exhibiting their instruments at Världskulturmuseet in Göteborg in 2024. The exhibition will have a mystical forest theme, with a tree as a centre piece, and MISK-instruments surrounding the tree mounted on walls and floor. After a meeting regarding this exhibition held after the workshop, an important decision for my project was made. Through discussions with my supervisors and the pedagogues at Eldorado, we decided to get inspiration to my musical instrument from the centre piece tree, specifically the tree branches. This meant narrowing down the interaction to something that could be expressed hanging from a tree branch, and that would fit the theme and the construction of the exhibition. The figure below shows a rough sketch of how the exhibition room could possibly look.

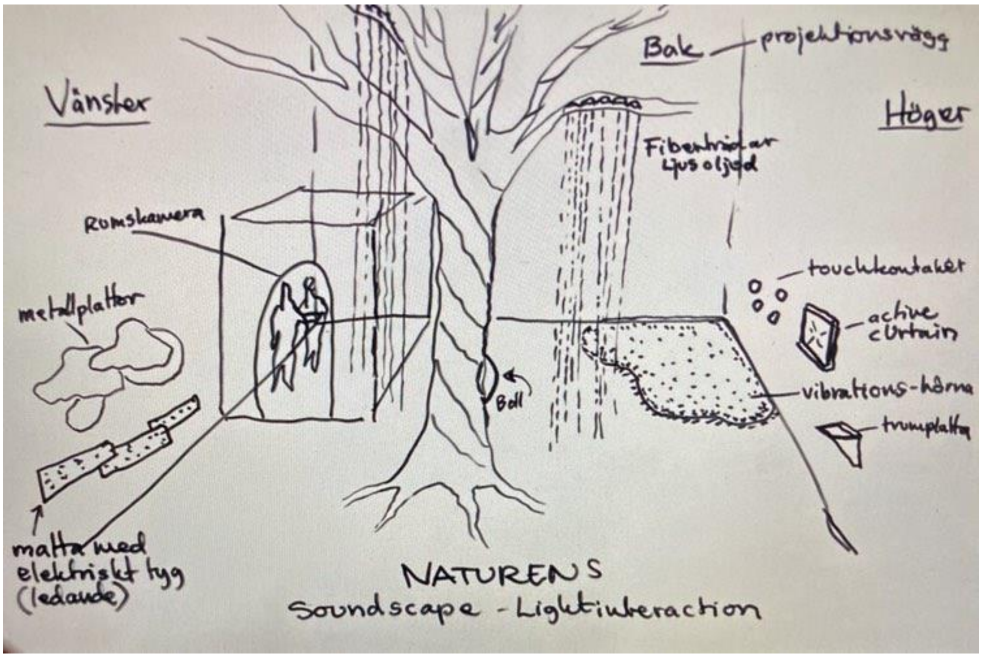


Figure 11 – Rough sketch for the exhibition at Världskulturmuseet (MISK-project, 2023)

Inspiration was taken from "Luftrummet", the air room, at Eldorado, where fibre optics are hanging from the roof, and lit up using an LED with a small controller that can be adapted to the room's lighting. A similar light is shown in Figure 12 - Fibre optic curtain (Komikapp, 2023) below. We discussed the possibility of controlling the lights and the fibre optics with the MISK instrument through some kind of interaction, either by touching the fibres, or by picking up sound through a microphone.

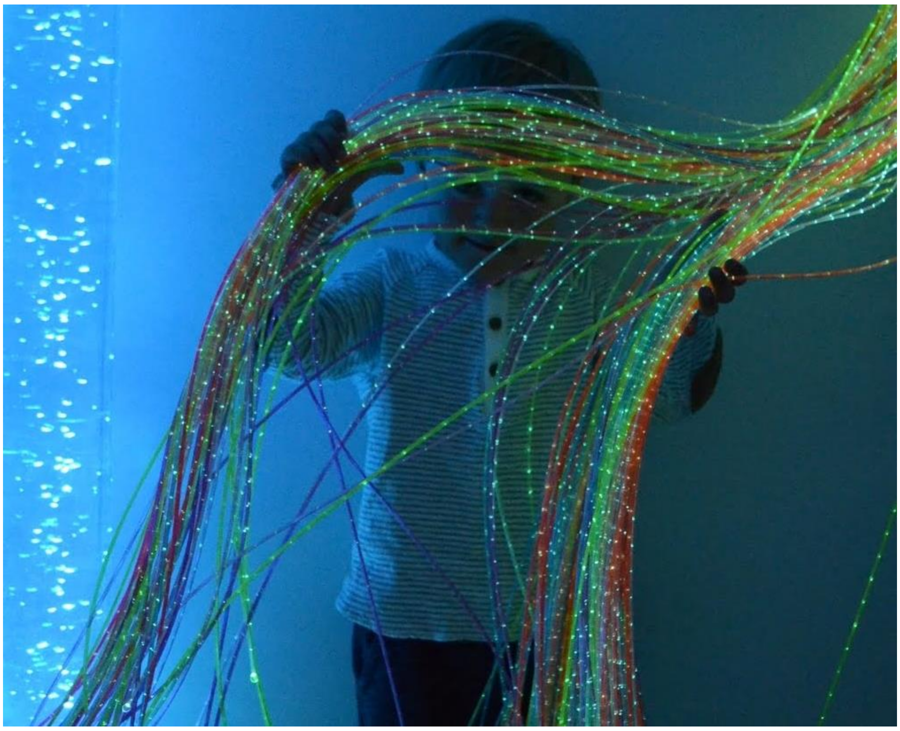


Figure 12 - Fibre optic curtain (Komikapp, 2023)

Figure 13 - Tree of Souls from *Avatar* (Pinterest, 2023)

Requirements for the musical instruments were formulated to match the idea for the exhibition. Since the tree is in the centre of the room, it is desirable that it matches the theme and somehow fills out the room. An important requirement is that it is sturdy, both the physical construction and the controls. It was discussed to make the tree have several branches, making it desirable that multiple users can play on it at the same time, and to make it possible to expand the construction.

These requirements are added to the previous ones to ensure that it fits into the exhibition:

- The instrument should fill out the room.
- It should be usable for multiple users.
- Possible to expand to multiple branches
- It should fit into the mystical forest theme.
- It should be sturdy enough to withstand children's play.
- It should use some type of hanging lights to simulate a mystical tree.
- The interaction with the tree should be done by touch or through picking up surrounding sounds

5 Define

5.1 Discovering requirements

5.2 Function analysis

The initial requirements from the project scope (0), universal design principles (2.4) and statements and observations from the two workshops are translated into functions in the instrument. The table marks essential [E] and desired [D] functions. Commonly, a column for unnecessary functions is included in the function analysis. However, none of the included functions was determined to be unnecessary and this column was therefore removed.

Table 1 - Function analysis

Function	E	D
Playing music	X	
Customizable sound		X
Customizable material		X
Haptic feedback		X
Uses LED lights		X
Available components	X	
Sturdy	X	
Compatible with MISK	X	
Compatible with exhibition visuals		X
Hanging from roof/branch		X
Clear feedback	X	

Low price		X
Inspires use	X	
Usable for multiple users		X
Looks like a real instrument		X
Fills the room		X
Tolerance for error	X	
Simple and intuitive use	X	
Flexibility in use	X	
Low physical effort	X	
Size and space for approach and use	X	
Quick setup		X
Safe to use (chewing, pulling…)	X	
Fills out the room		X
Has hanging lights		X
Possible to expand		X

5.3 Design brief

The design brief from the MISK-project is completed with requirements found in the *discover* phase. The new design brief, from where the next step in the design process has its starting point, is formulated as follows:

Develop a new type of technical-mediating and multi-sensory musical instrument, that is adaptable based on the user's resources and interests, i.e., movement abilities, individual ways of communication and sensory and musical preferences. The instrument should be mountable on a tree branch and withstand use in a public exhibition environment.

5.4 Concept generation

To explore as many different types of musical interaction as possible, a brain storming session was done, and the concepts generated during this session are shown in the figure below. After the workshop at Eldorado, the scope of the project changed slightly, and the generated concepts in this session, being done before the workshop, became less relevant. However, the idea of using rainbow colours to give the user feedback when playing was kept into the next phase, the prototyping phase.

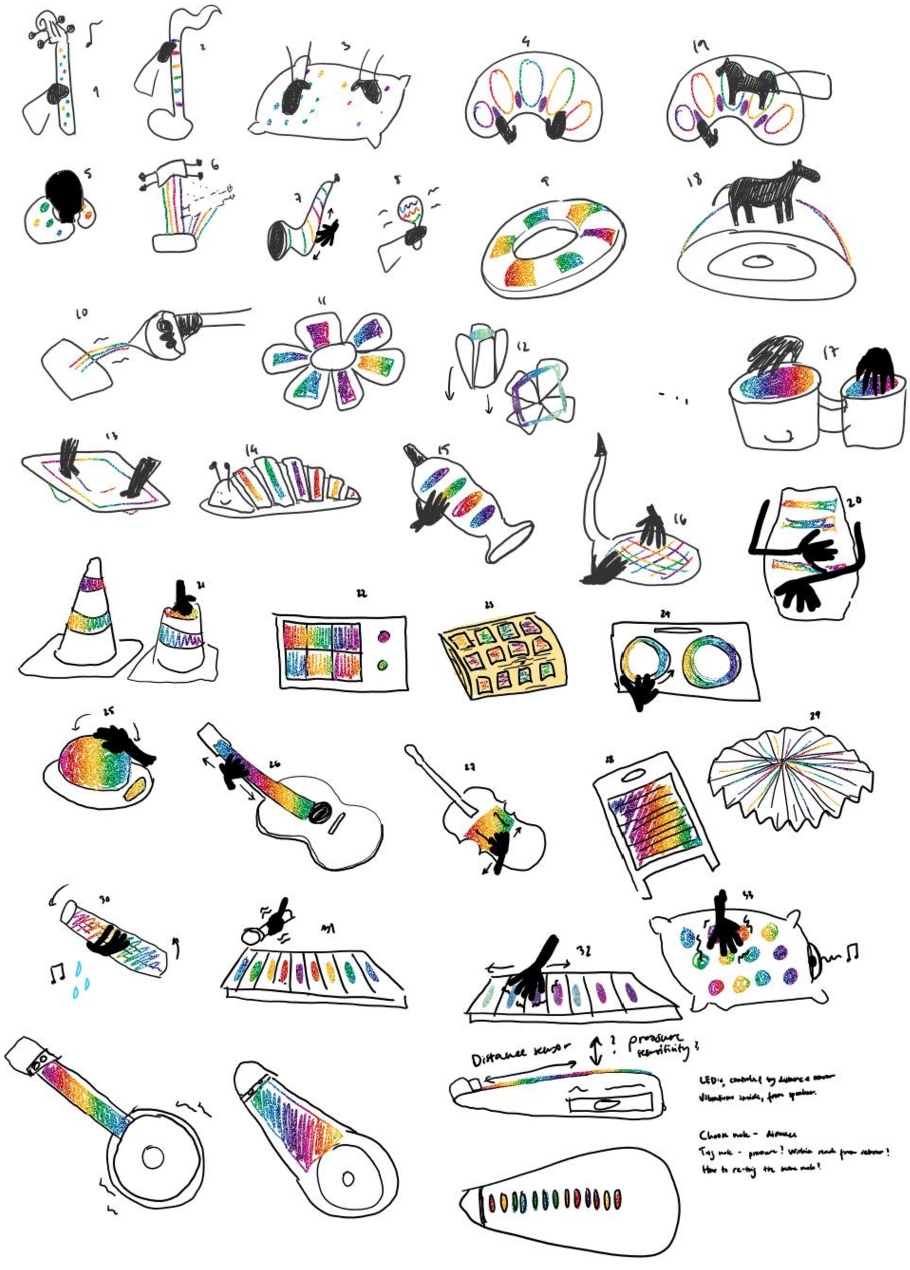


Figure 14 - Concept ideas – brain storming on possible interaction types

6 Develop

6.1 Prototyping

6.1.1 **Digital prototyping and compatibility with MISK software**

The prototyping phase was partly conducted in parallel with the define stage of the design process. The first stage of the prototyping was to become familiar with the existing MISK-software and the Arduino working platform, getting basic sensors to work together. To fulfil the essential function *compatibility with MISK*, the Arduino must communicate with the MISK software. There are several ways to do this, and for this project it is required that the instrument "speaks" to the MISK-software using the OSC-protocol, described in section 2.7.3. This method has been used in previous MISK-applications and enables a freer setup that does not require to physical connection to a computer.

6.1.2 **Physical prototyping**

The hardware and physical appearance of the instrument was developed in parallel with the digital prototyping. Since the type of sensor chosen will decide a lot about the instrument layout, it was important to get a stable prototype with a working concept, and the physical layout and design of the instrument was secondary priority, to be done when the sensors were working.

6.1.3 **First iteration**

The first prototyping iteration was a fibre optic strands lamp bought from Amazon, where the LED-light was replaced and controlled by the Arduino. Three microphones were connected to the Arduino and when detecting a noise, they lit up the LED in red, blue or green. The initial idea was to use contact microphones, that are described in section 2.8.1, but I did not manage to get the piezo elements that I bought to be sensitive enough. I therefore used the electret microphones, described in section 2.8.2, which reached a better level of sensitivity. To increase

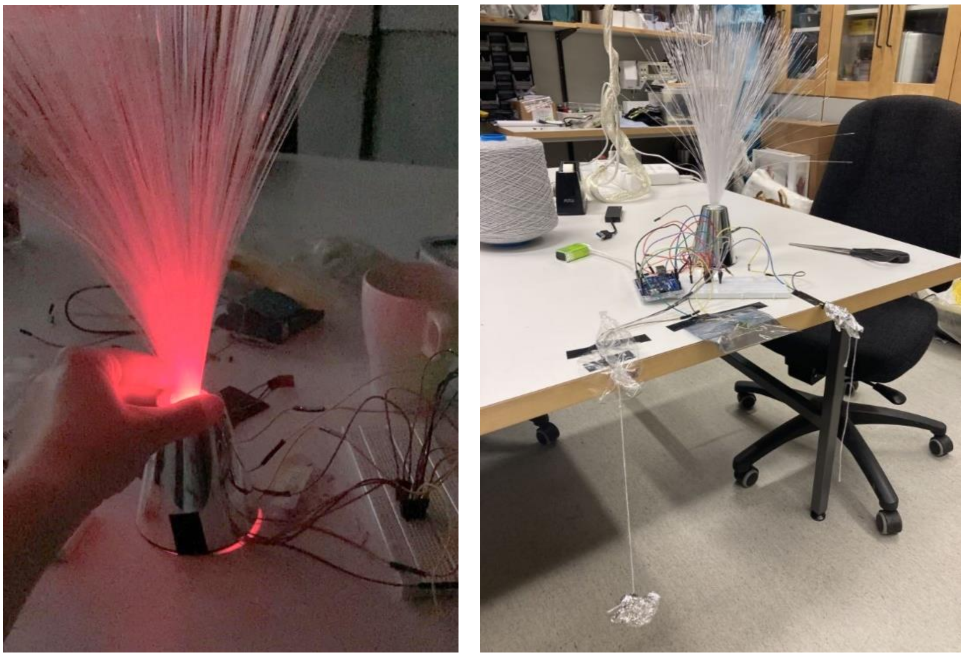


Figure 15 - The first prototyping iteration

their sensitivity even more, I experimented with covering the microphones in different materials, as shown in the picture below. The sound of plastic being crumbled was giving off s signal from the microphone, making the bags and threads playable.

6.1.4 Second iteration

After testing the microphones, we tried a library and a setup for the Arduino that supports capacitive sensing, described in section 2.8.3 (GitHub, 2023). The Arduino has a limited number of pins, and using the CapSense library enabled the use of more sensors, using it together with two breakout PCBs, MPR121 touch controls, supporting 12 sensors each. The library also worked when sending OSC-messages over Wi-Fi, making it a good fit for this prototype. To get the sense of a tree branch, the threads were mounted on a plastic pipe and hanged in the roof. A LED-strip was mounted underneath the plastic pipe. Conductive threads were tied to the pins of the PCB. When the conductive threads are being touched, the Arduino senses the change in capacitance and a corresponding part of the LED-strip lights up. The Arduino sends an OSC-signal of which sensor has been touched, which the MISK-program can read and play the synth accordingly.

Additionally, Ø1 mm fibre optics were bought, cut, and mounted in a bundle over the LEDs. The fibres were braided and heated with a heat gun, causing them to emit light more evenly, as shown in the picture below.

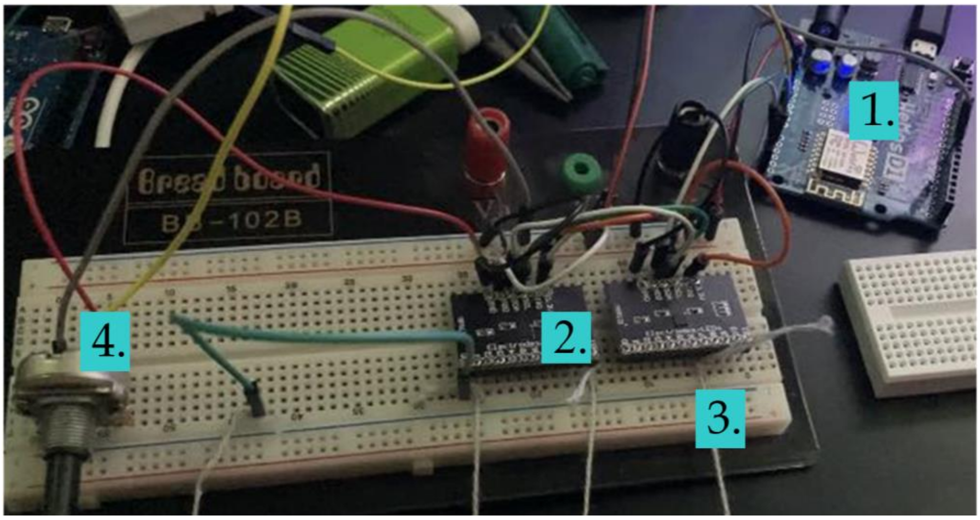


Figure 16 - The electronics setup. 1: The WeMos board. 2: The PCBs for capacitive sensing. 3: Conductive thread. 4: Potentiometer for calibrating sensitivity threshold

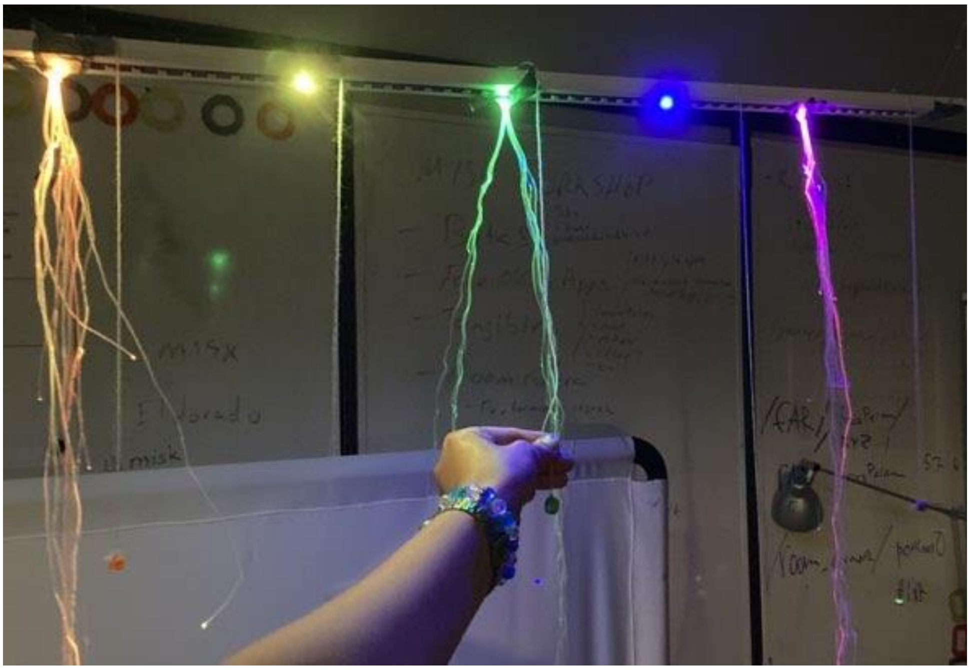


Figure 17 – The LEDs, hanging threads and fiber optics.

6.1.5 Testing the first prototypes

The initial prototypes were continuously tested in the Certec-lab by me and my supervisor. The sensitivity level was calibrated by changing the threshold in the Arduino Library. As shown in the figure above, a potentiometer was installed to make the threshold calibration more effective. We tried making the sensors as sensitive as possible without excessive undesired noise. The sensitivity of the sensors would ideally be very high, making the threads playable with light touches. However, with the library at hand and with the current setup, the threads needed to be pinched with two fingers to give off a clear enough signal.

Although the sensitivity of the capacitive threads was lower than expected, this second prototype was fulfilling many of the crucial and desired functions and was used as a base for the final prototype.

7 Deliver

7.1 Final Prototype: The Magic Tree

Reaching the last part of the Double Diamond, the deliver phase, the final prototype was built and tested. The concepts from the first prototypes were refined and mounted into a sturdier build. This third iteration of prototyping is a high-fidelity prototype of the concept, that I have chosen to call The Magic Tree.

7.1.1 **The tree branch**

The Magic Tree is built from a tree branch from my parents' house, from a tree that I used to climb as a child. The branch is around 1,5 meters long and has a diameter around 50 mm and has hooks from where it can be hung from the roof. On top, the branch has flat surfaces where the Arduino board and the bread boards holding the capacitive sensors, fit. A groove is carved out where the LED-strip sits, holding 60 LED lights. On the underside, the branch has drilled out holes aligning with the LED:s that fit ~20 pieces of fibre optic cables, that are squeezed into the holes and glued. Using a real tree branch makes the prototype cheap, sturdy and the instrument instantly looks like a tree. It is also relatively easy to manipulate with hand tools and adapt into fitting the electronics.

Metal wires were bent and hammered into the branch. The 20 sensors connected to the Arduino were twisted onto the metal wire, and conductive threads were tied onto the metal wire, relieving stress from the electronics, but keeping the connection.

Figure 18 - The metal wires with twisted cables and and conductive threads

Figure 19 - Capacitive threads and fiber optic strands

Figure 20 - The WeMos board mounted on the branch

Figure 21 - The breakout board mounted on the branch, and LED strip underneath

Electronics

In addition to using the WeMos board, described in section **Error! Reference source not found.**, the two breakout boards for capacitive sensors from the previous iteration, connecting tables and a LED-strip is used. The board is driven by a 12V power source, like a battery or a power plug. The setup of and the MPR121 breakout boards are shown in the circuit diagram below. Highlighted in yellow are the 20 sensor inputs, where 20 cables leading to the metal wires are attached, making out the notes for the instrument.

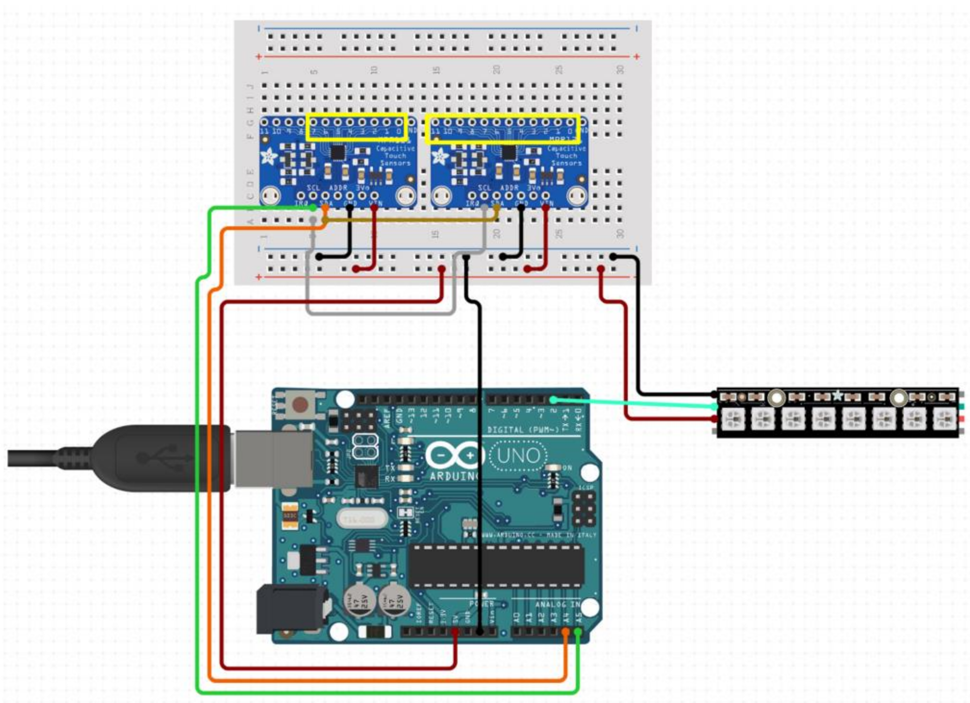


Figure 22 - Circuit diagram (Drawn in circuit.io)

The board in the figure is an Arduino Uno board. The circuit.io application does not have the WeMos-board among its components. The circuit would looks very similar with the WeMos board. The only difference is that the WeMos board only has one analogue input (bottom right corner) and both MPR121 boards are connected to this input. The LED-strip in this figure has only 8 LED:s but my prototype has 60. The connections are still the same.

7.1.2 **Software**

The code for all of the prototypes is written in C++ in the Arduino IDE. The general code structure is presented in a flow chart diagram, shown below.

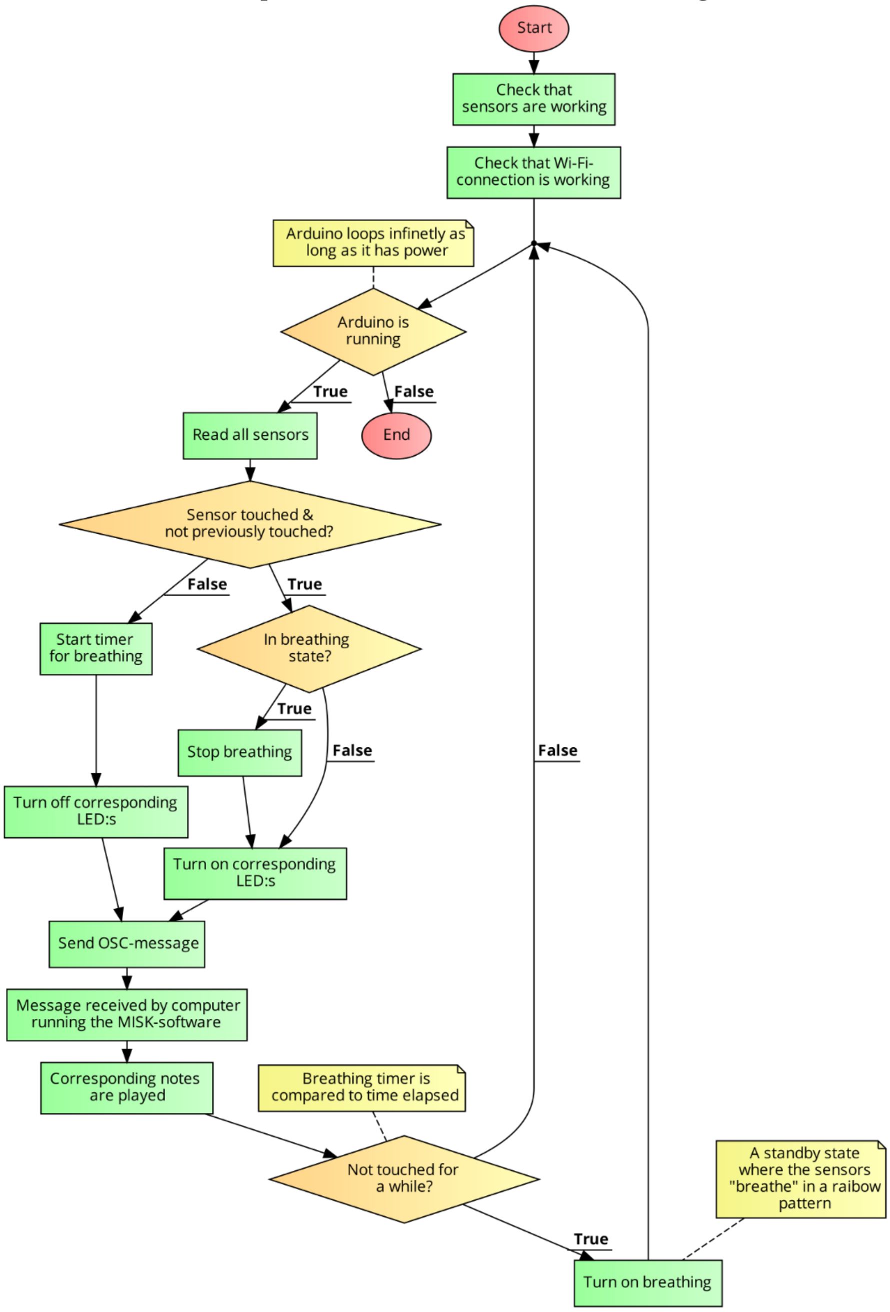


Figure 23 - Flow chart for Arduino program (Drawn with Code2Flow, 2023)

7.2 Testing the final prototype with pedagogues

The final prototype was tested with two pedagogues from the MISK-project. The testing was conducted in the Certec Lab, with the Magic Tree connected to the lab computer. The testing was done by setting up the instrument, and letting the pedagogues play on it freely. We experimented with manipulating the fibre optics and the capacitive threads, to test how it affected the sensitivity and the interaction. During the testing, experimentation was done with the MISK software, to test how it can be used to audiate the interaction with the branch. During and after the testing we had a reflective discussion on how the prototype is working, what works well and what can be improved.

Figure 24 - Testing the final prototype with pedagogues

Statements and observations made during the testing with the pedagogues can be summarised in the following bullet points:

- Combining the capacitive threads and fibre optics is an interesting concept that generally works well.
- The sensitivity would ideally be increased to allow for lighter touches to be recognised by the program.
- Using the MISK music software to adapt to the instrument can strongly enhance the experience when playing.
- The branch hanging from the roof, allowing for adjustment of height, is a good solution, but might require adaptation of the length of the treads.
- The mount of the capacitive threads is fairly strong but will need improvement to withstand an exhibition environment.
- The mount of the fibre optics is not sturdy and will need improvement.

- The fibre optics light up better when manipulated but will need better alignment with the LEDs and stronger light to be more clearly visible, especially in a well-lit room.

These bullet points make out the testing results from the final prototype and will be used as data for the fulfilment of functionality table in the next chapter.

8 Result

8.1 Final prototype and fulfilment of needs

When comparing the function analysis table from section 5.2, and the statements from the final test in section 7.2, the fulfilment of functions can be described by the updated function analysis table below. The table is filled out based on the testing with the pedagogues and their statements.

Table 2 - Fulfilment of functionality

F = fulfilled, P = partly fulfilled, N = not fulfilled		
Function	**E**	**D**
Playing music	F	
Customizable sound		F
Customizable material		N
Haptic feedback		N
Uses LED lights		F
Available components	F	
Sturdy	N	
Compatible with MISK	F	
Compatible with exhibition visuals		F
Hanging from roof/branch		F
Clear feedback	P	
Low price		F
Inspires use	F	
Usable for multiple users		F

Looks like a real instrument		N
Fills the room		F
Tolerance for error	F	
Simple and intuitive use	F	
Flexibility in use	P	
Low physical effort	P	
Size and space for approach and use	F	
Quick setup		F
Safe to use (chewing, pulling…)	P	
Fills out the room		F
Has hanging lights		F
Possible to expand		F

8.2 Fulfilment of functions

Of the essential functions, only the sturdiness is not fulfilled by the prototype. The sturdiness is marked as not fulfilled mainly because of the fibre optic threads not being able to withstand harder pulling without falling off. This is the first thing that should be addressed when continuing the development of this prototype.

Four functions, clear feedback, flexibility in use, low physical effort and safety to use is marked as partly fulfilled. The feedback is partly fulfilled due to the low visibility of the LED lights. The audial feedback is responsive, but with more visible lighting in the fibre optics visible the instrument would be much more intuitive to use. The flexibility in use and low physical effort both require a higher sensitivity in the capacitive threads, to allow users to play with more subtle movements. If this can be acquired, users without ability to hold and pinch the threads will still be able to enjoy the instrument.

While the instrument is not directly dangerous to use as it is, since the electronics are at a distance where the users cannot reach them and the capacitive threads and fibre optics are not carrying electricity, the hanging threads could invite the users to hang in them. In an exhibition environment, threads falling off when being pulled hard is undesired. The capacitive threads are easy to replace, but the fibre optic cables require more work to be attached. A solution to this could be to use thicker fibre optics, and to relieve tension from the threads by wrapping them around the branch or leading them through a plate. Inspiration can be drawn from the fibre optic curtain from Komikapp in the picture below.

Figure 25 - Fibre optics pulled through a plexiglass plate to relieve stress (Komikapp, 2023)

Looking back at the updated design brief from section 5.3, the Magic Tree succeeds to fulfil the design brief on most points. The instrument most clearly deviates from the design brief with its limited ability to be physically adaptable and withstanding a public exhibition environment.

When narrowing down the physical expression of the instrument to a tree branch, the possibility to adapt the material and playing technique is excluding users that prefer other materials and interactions types. Since the MISK project is working with developing multiple musical instruments simultaneously, the goal of the exhibition is to offer something for everyone in the exhibition (see Figure 11 – Rough sketch for the exhibition at Världskulturmuseet (MISK-project, 2023).

The Magic Tree does distinguish itself from other instruments in the MISK-project and from instruments on the market with its appearance and combination of wood and electronics. Although the interaction is similar to playing a synth, harp or guitar, the possibility to hang in the threads or sit under the branches and play with the full body does increase its availability.

9 Discussion

9.1 Compatibility issues and troubleshooting

Although the Arduino is a well-established platform for physical computing and contains a lot of well documented libraries and compatible sensors, making different libraries and functions work together turned out to be difficult in some cases. To be able to speak through the OSC-protocol an Arduino with Wi-Fi-compatibility was required. For this prototype, we tried both the Arduino Uno Wi-Fi and WeMos boards. When trying with the Arduino board, Wi-Fi connection and the capacitive sensing, the results were not good. When changing the sensos and the library to the one used in the last two prototypes, described in section 2.8.5, it was working with the WeMos board, and it was decided to use it for this prototype. It was never tested with the Arduino Wi-Fi, and using this different library might have worked.

As a result of some libraries and their associated sensors working better than others, this has affected the choice of sensors used in the final prototype. With more time available, more sensor types and libraries could have been tested and evaluated to find a more ideal setup for this project.

9.2 Time plan evaluation

The Gantt chart below represents the actual time spent on each activity, and their order, with the for phases of the Double Diamond on the very top.

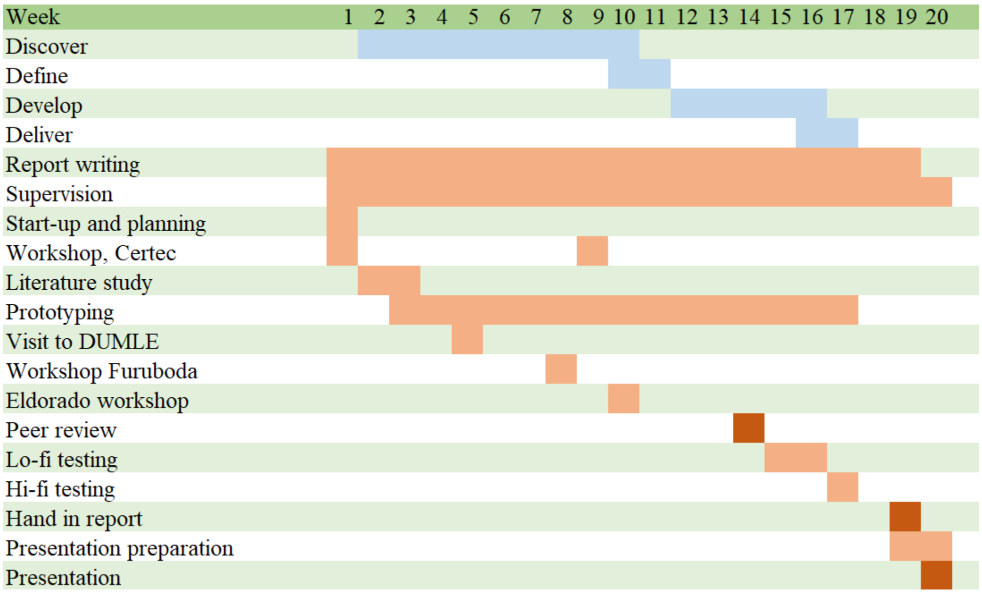


Figure 26 - Gantt chart according to reality

It is tricky to clearly distinguish where the phases of the Double Diamond design process begin and end, and the above is an estimate. What this Gantt chart shows compared to the chart made in the beginning of the project, is that the discover phase took longer than expected, and the define phase was faster. The deliver phase was started late in the project and could not go on for four weeks, as initially planned.

More time than planned was spent on early stages of concept generation and prototyping, resulting in less time left for finalizing and testing the prototype. The decision to build the Magic Tree was made after the workshop at Eldorado the 10th week of the project. Narrowing down the scope at an earlier stage would probably have resulted in more time to refine the final prototype.

9.3 Evaluation of the prototyping

9.3.1 **The first prototypes**

Throughout the design process, I was focusing on having a prototype with working electronics. Due to much time spent on troubleshooting code and electronics, mentioned in section 9.1 above, making a functioning prototype turned out to take long. Making simpler and analogue prototypes, more low fidelity and without electronics, would have been a way to test concepts of a wider scope and explore more different interaction types, being less controlled by what sensors were working and not.

9.3.2 **The final prototype**

Once the concept with capacitive sensing and the theme set for the instrument, the build of the final prototype was relatively quickly executed, due to a lot of groundwork laid in earlier stages of the project. Starting late in the project, only around two weeks were left to refine the concept. More time would have been available in this part of the project, but the 20 weeks were coming to an end.

9.4 Evaluation of the testing

9.4.1 **Testing of the first prototypes**

The test of the first prototypes was done by me and sometimes my supervisor in the lab continuously through the design process. This allowed for making small changes and doing development more effectively than it would have been setting up multiple testing sessions. Testing the prototypes with external users throughout the design process would however have given more insights about how intuitive the instrument was to use, and what the users preferred.

9.4.2 **Testing of the final prototype**

The choice to test the final prototype with the music pedagogues from the project was made for two reasons: firstly, they are the ones to use the instruments in their work and they possess a lot of knowledge about the user group. Secondly, the high-fidelity prototype was functioning late in the thesis process, and they were available on short notice.

Ideally, the prototype should have been tested more extensively and with the end users to get more user data. However, due to the physical prototyping taking longer than expected and the requirement to travel with the tree branch to Gothenburg, the choice was made to test it where it was built, in the Certec Lab at LTH. With more time available, the next step in the prototyping phase would be testing it with users. Hopefully, the MISK-project will continue developing this concept and test it on a workshop in the future. When bringing a prototype to Gothenburg it is desired that it works fairly well, not causing confusion and irritation among the users.

9.5 Implementation and further iterations

Due to the prototyping phase taking longer than expected refinement of the high-fidelity prototype could not be done within the time limit, and the project does therefore not include all parts the last phase of the Double Diamond design process, the *deliver* phase. After initial testing of the hifi-prototype, the product should be tested more extensively with the end user and developed into a prototype that fulfils all requirements from *Table 1 - Function analysis* and that is built to work smoothly at the exhibition at Världskulturmuseet. This requires making both the running code, the electronics, and the physical construction of the Magic Tree sturdier, to pass the ultimate sturdiness test, playing children.

9.6 Method evaluation

Using the Double Diamond design process for this project was mostly successful. The choice of following the Double Diamond design process was made in the beginning of the project. During the course of the work, the process was altered to fit into the time schedule, my way of working and the scope of the project. This resulted in my process diverging from the traditional way of working with the Double Diamond. The method leaves options to the users, and I decided to treat it like a framework rather than a detailed list of steps to follow, resulting in an adapted version of the process described below.

9.7 Double Diamond adapted to this project

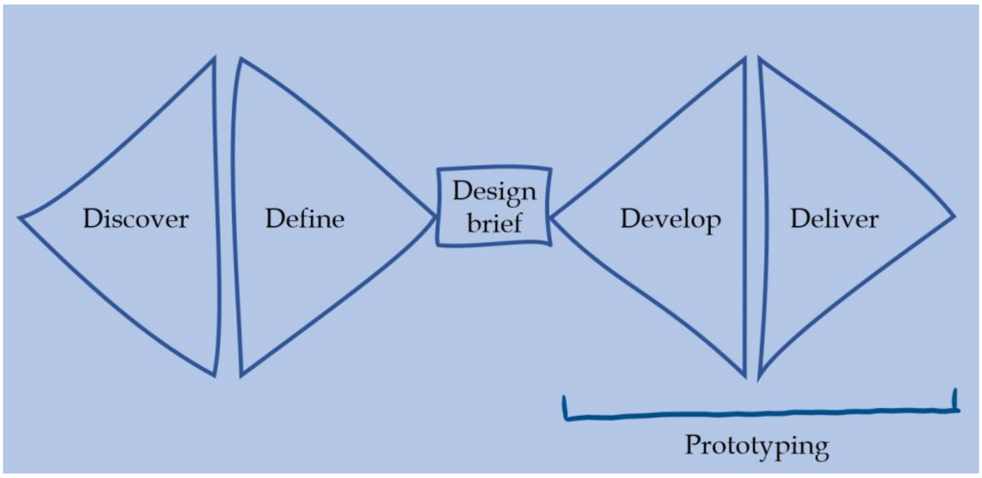


Figure 27 - My Double Diamond process

9.7.1 **The discovery and defining phase**

When starting the project, the scope was widely set to include all types of interaction and instrument types. This turned out to post a challenge to the design process. After doing user research, I had collected a lot of information and inspiration but with limited time to evaluate all of the ideas. My ambition was from the beginning to have a playable prototype at the end of the project, and to achieve this, I made the decision to focus on an almost finished concept after formulating the design brief.

9.7.2 **The prototyping phase**

Following the traditional Double Diamond process, after the defining stage, the develop stage is starting. In my process, the develop and delivery stages were merged together into what I have decided to call the *prototyping phase*. The reason for this was the combination of an ambition to present a playable prototype and limited time within the project. After making a decision to pursue one concept in the defining stage, the second half of my design process was focused on refining this concept through iterative prototyping. It is therefore difficult to definitely say where the develop stage ends, and the deliver stage begins. I have in this project defined the develop stage as the first two prototypes, and the delivery stage as working with the final prototype. This was done to make sure the delivery of a playable prototype would fit within the time frame. Although this not strictly following the method, the prototyping phase was an important way to learn and to try out and test concepts immediately.

Looking back, the project could have been done with more focus on exploration and low-fi prototypes, allowing for more concepts to be tested. This would have opened up to more possible solutions, but it would have limited the time to finish a functioning prototype. Since the ambition was to deliver a playable prototype at the end of the 20 weeks, the adapted method was fairly suitable.

10 Conclusions

10.1 Key findings

The key in this project is the implementation and testing of a combination of capacitive sensors, data transmission over Wi-Fi and a branch construction that work together. The capacitive sensing technique using conductive sewing threads proved to be a useful technique for the MISK-project to continue working on. The implementation of light and fibre optics in this project both has strengths and weaknesses that the MISK-project can learn from.

Another important takeaway from this project is that universal design places great demands on the product, and to make a digital instrument very sturdy and responsive requires extensive calibration and wise material choices.

10.2 Answering scientific questions

How can a musical instrument compatible with MISK be designed?

- What sensors and materials can be used?

This project explored the use of capacitive sensing using conductive thread. This proved to be a relevant technique for the instrument and I would recommend using this technique in further instrument development. Using wood as a base material was also working well, fulfilling the needs of being visually appealing, sturdy and easy to manipulate.

- How should the interaction work?

There are multiple ways of implementing the interaction and I have only explored one. The feeling of playing the fibre optic strands themselves is a pleasant experience that is interesting to further explore.

- How can the instrument be built to work in an exhibition environment for children, together with other MISK-instruments?

The instrument needs to be compatible with the MISK-software, and to fit into the MISK “feeling”. The most important aspect of the design is to make it safe and sturdy. By using the capacitive threads and fibre optics, the user can be placed far away from the electronics, reducing the risk when using it. There is however work left to work on in my prototype, especially in the physical construction of the electronics and assembly for it to withstand the exhibition environment.

10.3 Future work

Future possible improvements and additions to the Magic Tree is most importantly improving its main features, such as adding stronger lights and thicker fibre optics, and improving the assembly of the fibre optics and electronics, making it more resilient when used. The sensitivity of the capacitive threads can also be improved, by trying various Arduino libraries and/or different types of thread. It would also be relevant to further experiment with the Magic Tree together with the MISK application to test different sounds and effects to match the features of tree branch even better.

To stimulate more senses, a vibration floor or vibrations to the branch itself could be added to make instrument even more multi-sensory. Adding a y-parameter to the interaction, intensity of the playing e.g., is also a way to add more functions and enable new ways of playing on the Magic Tree.

References

[1] MISK Website (2023). *Arvsfondsprojektet MISK. https://goteborg.se/wps/portal/enhetssida/eldorado/kunskap/misk*

[2] Södermalm, L., & Nordlund, M. (2019). *Omsorgsboken* (Sixth edition). Sweden, Liber.

[3] UN General Assembly (2007). *Convention on the Rights of Persons with Disabilities*. Read August 15, 2023. https://www.refworld.org/docid/45f973632.html

[4] Carehome UK (2023). *Types of physical disabilities.* Read August 15, 2023. https://www.carehome.co.uk/advice/types-of-physical-disabilities

[5] ISO 21801-1:2020 (en), Cognitive accessibility — Part 1: General guidelines, read April 4, 2023, https://www.iso.org/obp/ui/#iso:std:iso:21801:-1:ed-1:v1:en

[6] Certec (2023), *Universell design*. Read March 3, 2023. https://www.certec.lth.se/ud/

[7] SID Project Website, https://sid.desiign.org/

[8] Snoezelen Website (2023). [Snoezelen – Multi-Sensoral Environments]. Retrieved March 3, 2023, from http://www.snoezelen.info/history

[9] Svarrer Larsen, H. (2015). *Tangible participation - Engaging designs and design engagements in pedagogical praxes* (PhD Thesis, Certec – Rehabilitation Engineering and Design, Department of Design Sciences LTH, Lund University, Lund, Sweden). Retrieved from https://lup.lub.lu.se/search/files/5751996/5265747.pdf

[10] Göteborgs Universitet (2023). *Musikpedagogik.* Read July 19, 2023. https://www.gu.se/scen-musik/var-forskarutbildning/musikpedagogik

[11] Johnels, L., & Vehmas, S., & Wilder, J. (2021). *Musical interaction with children and young people with severe or profound intellectual and multiple disabilities: a scoping review*. Department of Special Education, Stockholm Uniersity, Stockholm, Sweden. Retrieved March 2, 2023, from https://www.tandfonline.com/doi/full/10.1080/20473869.2021.1959875.

[12] Cycling74 website (2023). *What is Max?* Read August 18, 2023. https://cycling74.com/products/max

[13] Arduino website (2023). *What is Arduino?* Read July 19, 2023. https://www.arduino.cc/

[14] Wright, Matt (2002), *Open Sound Control Specification 1.0, Read July 10, 2023.* https://opensoundcontrol.stanford.edu/spec-1_0.html#introduction

[15] MIDI Manufacturers Association (1991). *MIDI Show Control (MSC) 1.0 Recommended Practice.* Retrieved July 19, 2023. http://www.richmondsounddesign.com/docs/midi-show-control-specification.pdf

[16] How Piezoelectric Speakers Work, read July 14, 2023, https://www.allaboutcircuits.com/technical-articles/how-piezoelectric-speakers-work/

[17] Open Music Labs (2023). *Eleclet microphones.* Read July 20, 2023. http://www.openmusiclabs.com/learning/sensors/electret-microphones/

[18] Picture: Electrokit (2023). *Piezoelement.* Retrieved August 18, 2023. https://www.electrokit.com/produkt/piezoelement-o20mm-sladdar-7bb-20-6l0/

[19] Picture: Electrokit (2023). *Electret mikrofon*. Retrieved August 18, 2023. https://www.electrokit.com/produkt/electret-mikrofon-o6-0-x-2-7mm-med-sladdar/

[20] Texas Instruments (2021). *FDC1004: Basics of Capacitive Sensing and Applications.* Read July 19, 2023. https://www.ti.com/lit/pdf/snoa927

[21] Picture: AliExpress (2023). Fiber optic light. Retrieved July 20, 2023. https://www.aliexpress.com/item/32803305564.html

[22] Picture: Keyence (2023). What is a fiber optic sensor?. Retrieved August 23, 2023. https://www.keyence.com/ss/products/sensor/sensorbasics/fiber/info/

[23] Picture: https://www.komikapp.se/fiberoptik-farg-100-tradar-2-m/

[24] Picture: Pinterest (2023). *Tree of souls.* Retrieve August 15, 2023. https://i.pinimg.com/originals/27/d5/94/27d59496022fb85b0a8a75f6f9933797.jpg

[25] Autodesk Instructables (2020), *How to Use Arduino WeMos D1 WiFi UNO ESP8266 IOT IDE Compatible Board by Using Blynk.* Read August 14, 2023. https://www.instructables.com/Arduino-WeMos-D1-WiFi-UNO-ESP-8266-IoT-IDE-Compati/

[26] Picture: Electrofun (2023). Retrieved August 18, 2023. https://www.electrofun.pt/858-large_default/wemos-d1-r2-wifi-esp8266.jpg

[27] Picture: Electrokit (2023). Retrieved August 18, 2023. https://www.electrokit.com/produkt/mpr121-touchkontroller-12-kanaler-i2c/

[28] Design Council (2007). *A Study of the Design Process.* Design Council, London, UK. Retrieved March 6, 2023, from https://www.designcouncil.org.uk/our-work/skills-learning/resources/11-lessons-managing-design-global-brands/

[29] Design Shack (2023). *What is a design brief?* Read August 18, 2023. https://designshack.net/articles/business-articles/what-is-a-design-brief/

[30] Sharp, H., & Rogers, Y., & Preece, J. (2019). *Interaction Design: beyond human-computer interaction* (Fifth Edition). United States of America, John Wiley & Sons.

[31] Begripsams etiska ram. Read April 4, 2023, https://www.begripsam.se/om-oss/begripsams-etiska-ram

[32] United Nations, Conventions on the Rights of Persons with Disabilities (2008), Read April 4, 2023, https://www.ohchr.org/en/instruments-mechanisms/instruments/convention-rights-persons-disabilities

[33] Johansson, S, (2016). *Towards a framework to understand mental and cognitive accessibility in a digital context,* KTH Royal Institute of Technology, Stockholm, Sweden. Read April 4, 2023, from http://kth.diva-portal.org/smash/record.jsf?pid=diva2%3A908641&dswid=-4194

[34] Musii website (2023). Read July 19, 2023. https://musii.co.uk/

[35] Quha website (2023), Quha Zono, Gyroscopic mouse for special needs, Read July 19, 2023. https://www.quha.com/products/quha-zono/

[36] EyeHarp website (2023). EyeHarp, Music of the eyes. Read August 15, 2023. https://eyeharp.org/

[37] GitHub (2023). *AdafruitMPR121.* Read August 18, 2023. https://github.com/adafruit/Adafruit_MPR121

[38] Picture: Circuit.io (2023). Drawn and retrieved August 16, 2023. https://www.circuito.io/app?components=512,11021,216577,583741,583741

[39] Picture: Code2Flow (2023). Drawn and retrieved August 18, 2023. https://app.code2flow.com/