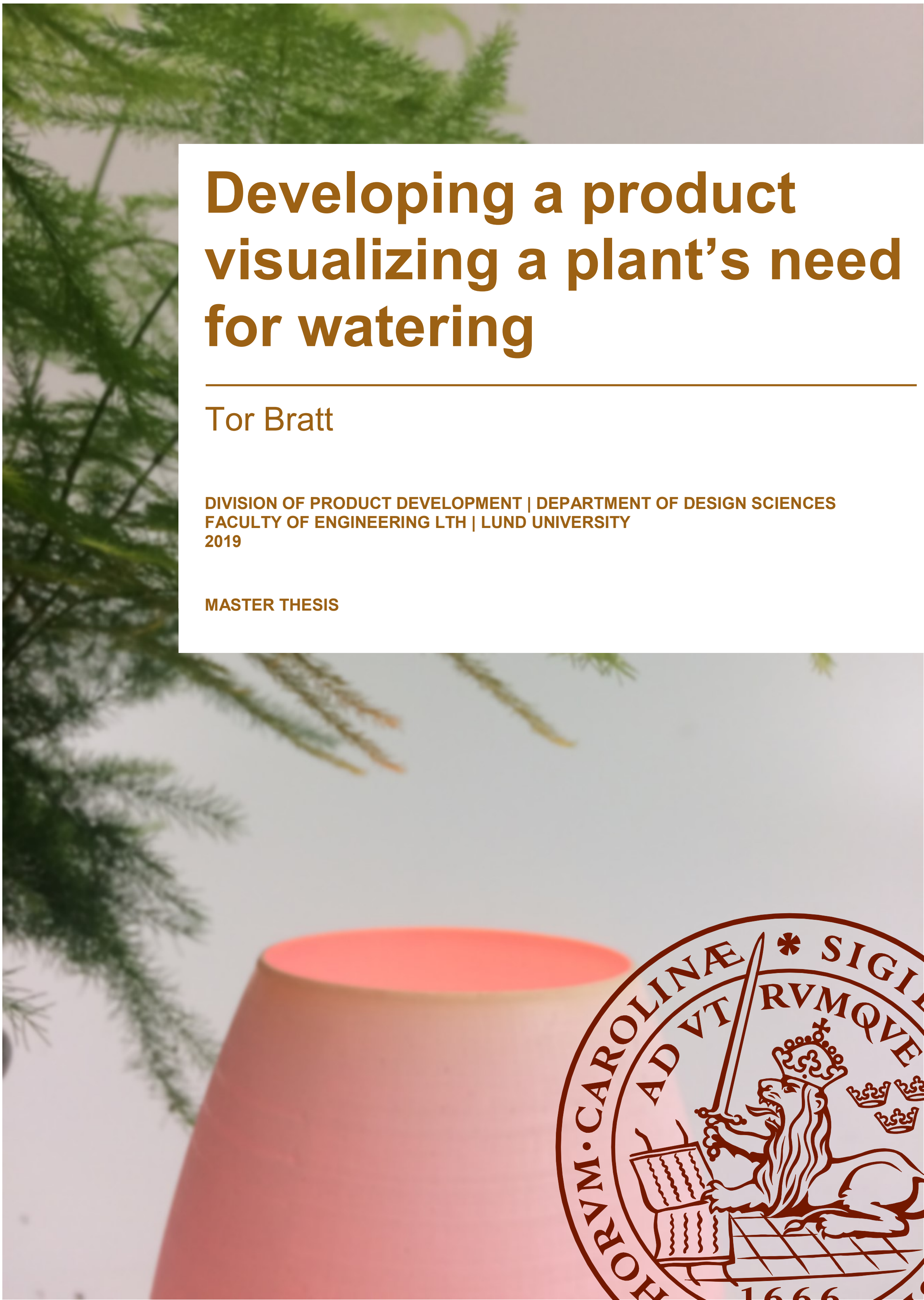


Developing a product visualizing a plant’s need for watering

Tor Bratt

DIVISION OF PRODUCT DEVELOPMENT | DEPARTMENT OF DESIGN SCIENCES
FACULTY OF ENGINEERING LTH | LUND UNIVERSITY
2019

MASTER THESIS

Developing a product visualizing a plant's need for watering

Making the nursing of houseplants easier

Tor Bratt

LUND UNIVERSITY

Developing a product visualizing a plant’s need for watering

Making the nursing of houseplants easier

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: Department of Design Sciences
Supervisor: Per Kristav
Examiner: Axel Nordin

Abstract

Urbanization in the world has during the past 60 years accelerated, resulting in people living in more densely populated areas and spending a majority of their lives indoors. Another ongoing trend in many countries is an increase in mental health issues, where urbanization could be a contributing factor.

Studies have shown that closeness to nature increases our well-being. One way to achieve this indoors is by having indoor plants, or houseplants. However, a common issue with having houseplants in your home is that most of them need to be watered regularly to thrive. Living a stressful life, having no interest or lacking knowledge about houseplants easily makes you forget to water them, causing them to wilt or keeping you from having them in the first place.

This master thesis has the purpose of developing a product that that eases the nursing of houseplants, to encourage people to have more plants in their homes.

The design process started off by researching the cause of the problem, what solutions and aids that are available today and what target group that is in most need of the product. Based on this, the kind of solution that the thesis would focus on could be decided - Using light to increase the feedback received from a plant of its need for watering. Through the use of a persona and a design brief, a clear description of the task was then formed.

The development process started off by testing and evaluating the technical components needed for the solution. By making simple prototypes, user studies could be made to gain insights on how the feedback could be communicated in the best way. This eventually resulted in a concept for a product that was made into a final, functioning prototype.

The final concept is a type of lamp that through a moisture sensor visualizes a plant's need for watering. By placing the sensor into the soil of a plant pot, the lamp uses a red and green color scale to communicate the plant's access to water. The lamp is also programmed to turn on automatically when the soil becomes too dry, notifying the user when watering is due.

Keywords: Digital watering reminder, smart lamp, mood light, nursing of houseplants.

Sammanfattning

Urbaniseringen i världen har de senaste 60 åren accelererat, och folk bor numera allt tätare och spenderar större delen av livet inomhus. Samtidigt pågår en trend av ökad psykisk ohälsa i många länder, där urbaniseringen kan vara en påverkande faktor. Studier visar att närhet till natur gör oss mer välmående. Ett sätt att uppnå detta inomhus är att ha inomhusväxter. Dock är ett problem med att ha inomhusväxter att de kräver underhåll för att må bra. Lever man ett stressigt liv, har dålig kunskap eller saknar intresse är det lätt att glömma att ta hand om växter i sitt hem vilket kan leda till att de dör eller att man räds från att ha dem.

Detta examensarbete har som syfte att utveckla en produkt som underlättar underhållet av inomhusväxter, för att på så sätt uppmuntra folk att ha fler växter i hemmet.

Designprocessen startade med att undersöka varför problemet uppstår, vilka hjälpmedel som finns idag samt vilken målgrupp som är i störst behov produkten. Utifrån detta valdes sedan vilken typ av lösning som arbetet skulle rikta in sig på - Att med hjälp av ljus förbättra den feedback som ges av en växts behov av vattning. Genom bland annat en persona och en designbrief kunde sedan en tydlig beskrivning på uppgiften utformas.

Utvecklingsprocessen började med att testa och utvärdera de tekniska komponenter som behövdes. Genom skapandet av enklare prototyper kunde sedan användartester utföras för att få insikter i hur man på bästa sätt kan kommunicera vattningsbehovet för växter. Detta resulterade slutligen i ett koncept på en produkt, och tillverkningen av en fungerande prototyp.

Det slutgiltiga konceptet är en typ av lampa som med hjälp av en fuktsensor visualiserar en växts behov av vattning. Genom att placera sensorn i jorden på en kruka ger lampan med hjälp av en röd-grön färgskala användaren feedback på en växts tillgång till vatten. Lampan är även programmerad till att aktiveras automatiskt när fuktnivån blir för låg, för att underrätta användaren om att vattning behövs.

Nyckelord: digital påminnare för vattning, underhåll av inomhusväxter, mood light

Acknowledgments

The outcome of this master thesis would not have been the same without the insights and feedback gained from discussions throughout the project. I would like to thank the following people:

Fellow thesis workers Markus, Fredrik and Christian for your valuable feedback throughout the project.

Johannes Ekdahl Du Rietz for your help with the electronics.

The lecturers at Design Sciences for inspiring me and giving me ideas how to proceed in the project.

The staff in the workshops at Ingvar Kamprad Design Center for your help in making the final prototype.

Lund, January 2019

Tor Bratt

Table of contents

1 Background

1.1 Issue and aim

In the past 60 years, urbanization in the world has accelerated, resulting in people living in more densely populated areas. In 2018, 4.2 billion people lived in cities, compared to 751 million in 1950 (United Nations, 2018). As a possible effect of this, there has been an increase in mental health issues for people living in urban areas. With increasing levels of urbanization the incidence rates of psychosis and depression has risen (Sundquist, Frank, Sundquist, 2004). According to the Public Health Agency of Sweden, 39 percent of the population in Sweden aged 16–84 stated that they had mild or severe issues with anxiety or stress in 2018. This is an increase since 2016 when the proportion was 36 percent (Folkhälsomyndigheten, 2018).

A factor that could play a role in this is closeness to nature. Studies show that being exposed to natural environments can increase levels on well-being and reduce stress (Ewert & Chang, 2018). Living in an urban environment, the exposure to nature is limited and the time spent indoors makes up for a vast majority of people's lives. On average, Americans spends approximately 92% of their lives indoors (EPA, 2018).

One way to increase closeness to nature when indoors is by having indoor plants, or houseplants. However, houseplants are dependent on human interaction to be able to survive indoors. Most houseplants need to be watered regularly to keep growing and stay healthy. Living a stressful life or having limited interest or knowledge in houseplants can result in people having trouble keeping houseplants alive, or it might keep them from having houseplants in their homes.

Another reason why people have trouble nursing houseplants is that it can be hard to determine when a plant is in need of watering. It is not until the plant starts to show signs of wilting that visual feedback is received. It was therefore interesting, in this thesis, to study how the feedback received from a houseplant of its need for watering could be increased, thus making the nursing of houseplants easier.

2 Methodology

2.1 Project description

The goal for this project was to develop a product that makes the nursing of houseplants easier. By doing this, the larger goal was make people more interested in having house plants in their homes, without feeling restricted by the lack of time, knowledge or interest in caring for them. Another goal was to develop a product that in some way is unique and offers something that is not available on the market as of today.

The project was done as a design process, with the aim to develop a product that solves the main problem in the best possible way and fulfils the user needs discovered in the process. To be able to test and evaluate the concepts generated in the process, a goal was set to develop a functioning high-fidelity prototype of the chosen concept. The different stages of the design process were given a certain amount of time to be able to achieve this goal within the timeframe of the project. How the concept could be developed further is presented under 'Further Development'.

As the thesis was done as a design process, no specific solution was in mind at the start of the project. The final concept of the product was developed through an iterative process involving research, user-testing, prototyping and manufacturing.

The master thesis was carried out at the Department of Design Sciences at the Faculty of Engineering at Lund University during 20 weeks, starting the 3rd of September 2018 and finishing the 16th of January 2019.

2.2 Delimitations

- The final concept would only include technology and functions that had been tested during the development.
- As houseplants can be any plant that is located indoors, a delimitation was made to focus on domestic houseplants in people's private homes.
- The project was carried out with economic limitations, as it was done independently, without connection to a company. The goal was to be able to manufacture the final prototype with the resources available in the workshops at Ingvar Kamprad Design Center.

2.3 Double Diamond Design Process

The methodology used in the project was *The Double Diamond Design Process*. As seen in Figure 1, it consists of four phases: Discover, Define, Develop and Deliver (Design Council, 2019). This method was chosen as the project was a creative process with no specific solution in mind, which is encouraged in the Double Diamond Design Process. The four phases are further described below.

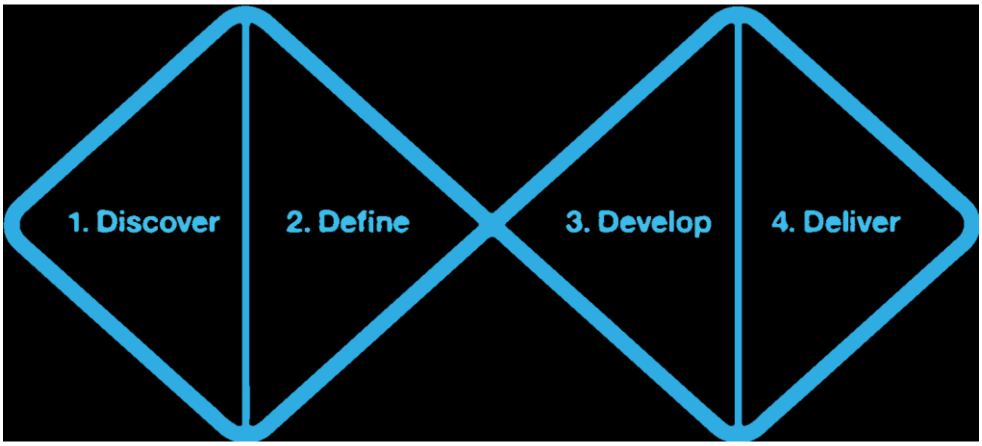


Figure 1. The Double Diamond Design Process.

2.3.1 **Discover**

The initial phase is divergent and aims to widen the knowledge in the relevant area. The aim of this phase is to gain insights about the cause of the problem and collect both quantitative and qualitative data. This was done by doing literature studies, user studies and a market research in the relevant area.

2.3.2 **Define**

The aim of the second phase was to use the information gathered in the Discover phase to specify the aim of the project and the problem that was to be solved. With the problem defined, a more detailed description of the task could be set up.

2.3.3 **Develop**

In the third phase the development of different concepts for the product was made. For this project, the majority of this phase consisted of testing and evaluating different technical components and prototypes to identify possibilities and challenges. Throughout this phase, user studies were done to get continuous feedback from potential users and gain useful insights.

This eventually resulted in the creation of three concepts for the product, and a decision on the final concept.

2.3.4 **Deliver**

In the fourth and final phase, the aim was to produce a functioning prototype of the chosen concept. Final user tests were also done to evaluate the prototype's ability to solve the main problem, while also gaining feedback on how it could be developed further.

2.4 Planning

A time schedule was made for the project, where the four phases of the design process were given a certain amount to time (Figure 2).

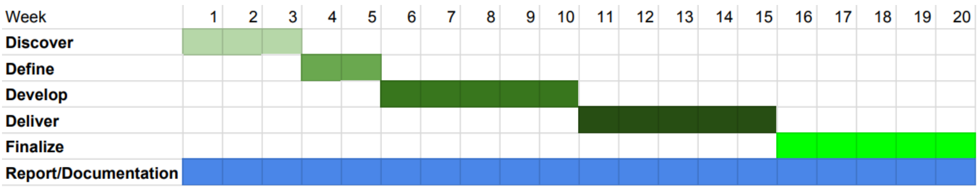


Figure 2. Initial time schedule for the project.

3 Discover

The aim of the Discover phase was to discover a problem connected to the nursing of indoor plants, and then decide what kind of solution the project would focus on.

This was done by researching indoor plants and what habits people have with them. A market research was then made to discover what different solutions are available for the identified problem, before choosing a solution to proceed with.

3.1 Literature studies

To get a better understanding of the subject of houseplants, literature studies were made. This research was made as if the main problem of the project had not yet been discovered, in the hopes that it would be discovered along the way.

When researching houseplants, the aim was to discover the following:

- How plants functions as living organisms, what their needs are and how these are fulfilled when placed indoors.
- How these needs differ between different types of houseplants.
- What the main reasons are for having houseplants.

3.1.1 What is a plant?

Plants are autotrophs, organisms capable of self-nourishment by using inorganic materials as a source of nutrients and using photosynthesis as a source of energy (Dictionary.com, 2019). Photosynthesis is a process used by plants to convert light energy into chemical energy (Figure 3). The chemical energy is stored in sugars, which are synthesized from carbon dioxide and water. Oxygen is then released as a waste product. Plants utilize sunlight, water and carbon dioxide to be able to grow (NE, 2019).

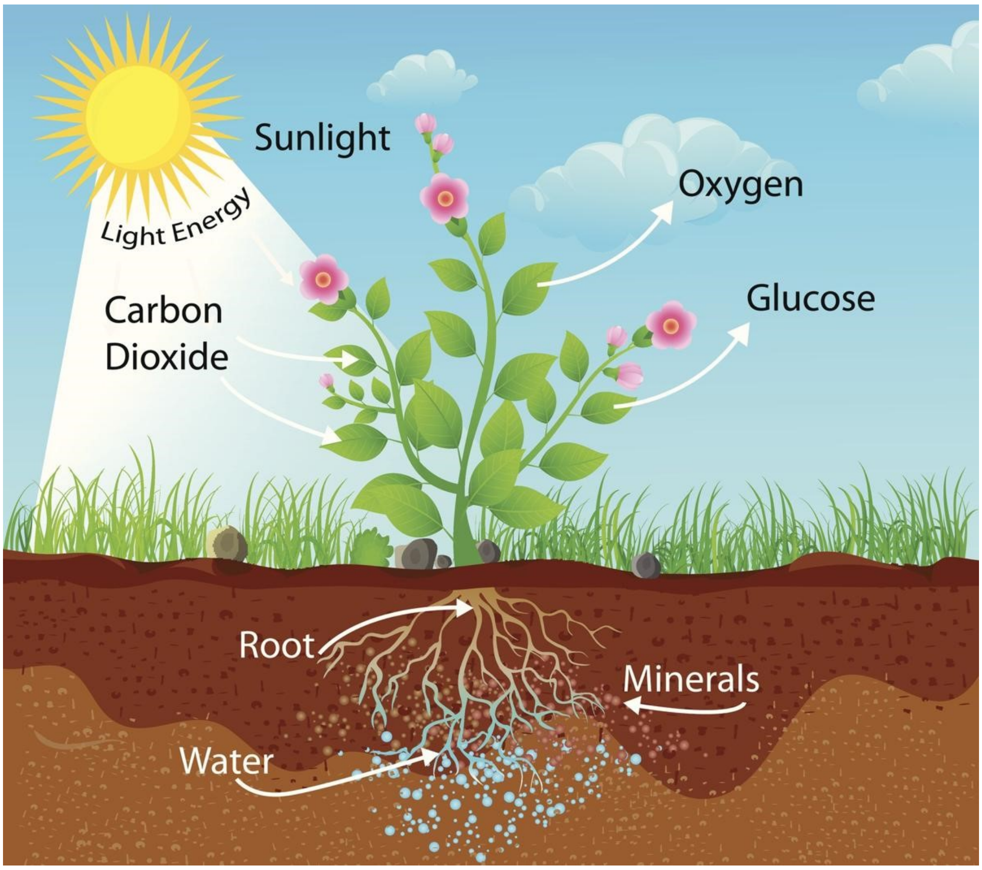


Figure 3. Photosynthesis, the circular flow of a plant (BiologyWise, 2018).

3.1.2 **What is a houseplant?**

A houseplant is a plant that is taken out of its natural habitat and is grown indoors. This means that the plant is placed in an environment that does not fulfil all of its needs to be able to survive. The needs are as follows (Planet Natural, 2017):

- **Water** - The plant and its root system need to have continuous access to water. Depending on the type of plant, the amount of water it needs and how often it needs to be watered varies, ranging from every other day to every second week or even longer.

- **Sunlight** - The plant needs enough sunlight to be able to perform photosynthesis. Different kinds of plants require different amount of sunlight.

- **Soil** - The soil that the plant rests in need to contain the right nutrients. Some plants consume nutrients faster than others, and the need to change soil or add nutrients varies.

- **Temperature** - Some tropical houseplants prefer warmer temperature, but most houseplants are tolerant to room temperature.

- **Humidity** - If the moisture level in the soil is sufficient for the plant, most plants tolerate if the humidity in the room is too high or too low.

- **Pot size** - The plant requires a certain amount of soil to be able to thrive. If a plant grows too big for its pot, it will need to be repotted into a larger one.

3.1.3 **Watering**

Plants use water in the soil by absorbing it into its root system. As the water is consumed, the soil in the pot gradually dries out. The speed of which a plant consumes the water depends on the size and type of the plant. Different plants require different amount of water. Different plants also respond differently to the lack of water or having too much water in the soil. Some plants have to dry out completely before watering, some need to become somewhat dry and others have to be kept moist all the time (Planet Natural, 2017).

Overwatering a plant will make the soil contain too much water, which stops the root system from absorbing oxygen that is needed for photosynthesis. Too much water can also make the root rot. Continuously adding too much water can eventually make the plant die.

Leaving a plant without access to water will make the soil dry after all water is absorbed by the plant. This leads to the plant drying out and eventually wilting. If a plant is not watered properly, the plant will start to drool or lose its color.

The need for watering will also change depending on the season. During the winter photosynthesis is slowed down due to cooler temperatures and less access to sunlight, resulting in lowered need for watering.

3.1.4 **Varying needs**

By the vast amount of plants that can be used as houseplants, their different needs tend to vary a lot. To simplify the different needs, a generalization was made by categorizing houseplants into three groups, based on their need for watering. (Plantagen, 2019):

- **Low maintenance** - Plants that need to be watered once every two or three weeks.

- **Medium maintenance** - Plants that need to be watered once every week.

- **High maintenance** - Plants that need to be watered once or twice every week.

3.1.5 **Benefits**

Other than being used for interior decorating, some studies suggest that indoor plants could improve psychological well-being and physical human health (RHS, 2019).

Some of the suggested benefits are:

- Reduced stress levels
- Increased well-being
- Increased worker productivity
- Improved attention span
- Increased pain tolerance
- Reduced blood pressure

Other studies also suggest that indoor plants help clean the air from contaminants, working as air purifiers. However, according to Luz Claudio, a professor in environmental medicine and public health, “There are no definite studies to show that having indoor plants can significantly increase the air quality in a room to improve hearth in a measurable way” (Time, 2018).

Key findings

- Plants have different requirements that need to be met when grown indoors.
- Compared to the other needs, access to water is the one that requires the most effort to maintain when nursing a houseplant.
- How frequently watering has to be done and how plants react to the lack of access to water varies.

3.2 Survey

To research people's habits and experiences with houseplants, a survey was conducted. The aim of the survey was to identify potential issues and needs that are connected to houseplants, as well as getting a better view of people's interest and knowledge on the area. To narrow down the target user group, an assumption was made that younger people to a greater extent are less experienced with houseplants. The target group was therefore set to men and women between the ages of 18 and 30.

To be able to rate people's knowledge, a numeric rating scale from 1 to 5 was used for some of the questions.

The survey was created digitally and distributed online. 93 answers were received in total from 41 women and 52 men. The average age of the participants was 26 years, and they lived almost exclusively in apartments. The full survey can be found in Appendix A.

3.2.1 **Results**

- The general interest in having and nursing houseplants varies from no interest at all (1) to a great interest (5) (Figure 4). Women are more interested than men (average 3.9 versus 2.5).

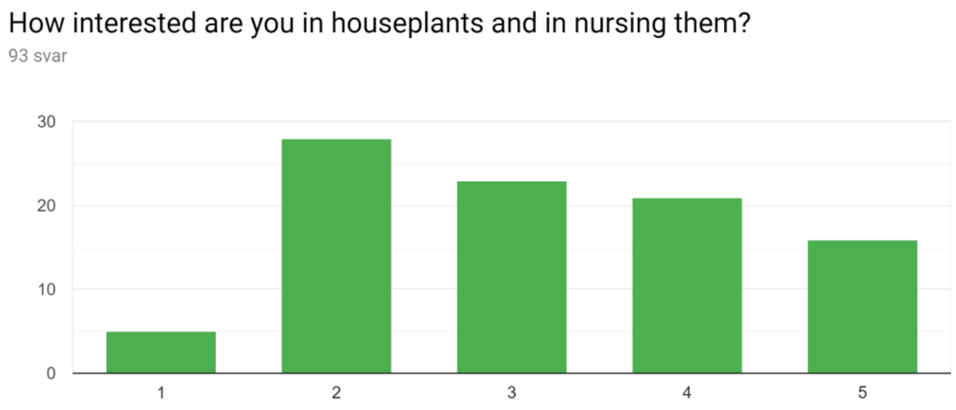


Figure 4. The general interest in houseplants and in nursing them.

- The general knowledge in keeping houseplants is rather low for a large group of the participants (Figure 5). In average, men put a score of 2, while women scored 3.

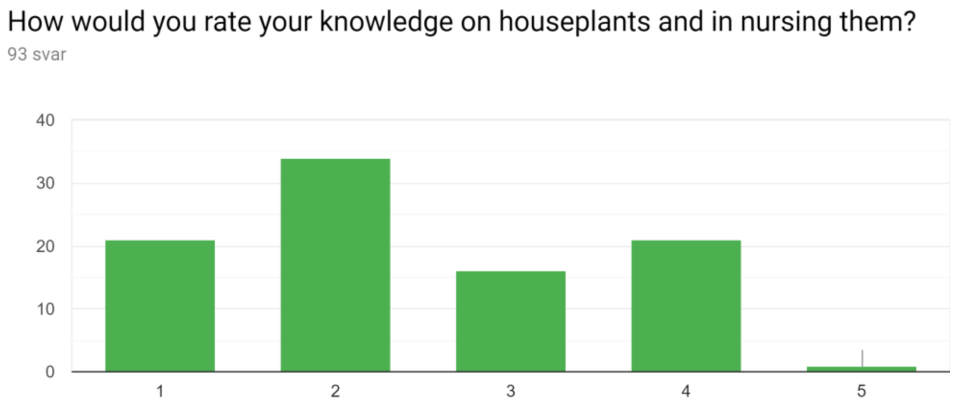


Figure 5. The knowledge of houseplants and in nursing them.

- Basically everyone participating have houseplants in their homes, ranging from only a few to more than thirty. Naturally, those with less interest in houseplants have fewer.

- The main reason for having houseplants is to make the home more lively and cozy.

- When asked what the hardest part is about having houseplants, the most common answer was watering. Those with a low interest in houseplants have trouble with watering in general, while those with a greater interest are more concerned about being away from home for longer periods of time.

- When asked about the method used to remember to water plants regularly, the most common answer was not having a method, and instead watering irregularly when it comes to mind. For those who answered that they have a method, these were the most common answers:
    - ❖ Having a routine, watering on a specific week day or every other day.
    - ❖ Noticing a plant starting to wilt and then water it.
    - ❖ Setting an alarm on your smartphone as a reminder.
    - ❖ Placing a filled water pitcher next to a plant as a reminder to water.
    - ❖ Checking the moisture level in the pot by placing a finger into the soil.

- When asked about that makes you forget to water, the most common answer was the lack of a routine, together with the lack of interest. Only 15% answered that they never forget to water.

- The frequency of watering varies greatly between the participants. A few do it every or every other day. The most common answer was once every week closely followed by more seldom, varying from one week to a month.

- The main method for determining how much water a plant needs is intuition, not knowing exactly what the plant needs and instead use an amount of water that feels right based on pot and plant size.

- When asked about how to determine if a plant is being watered in the wrong way, the most common answer was when it starts to wilt. Those with more experience check how the moisture level has changed since the last watering, determining if the plant needs less or more water.

- The self-estimated knowledge on how to nurse different kinds of plants is rather low with an average score of 2.5.

Key findings

From the information collected in the survey, the following conclusions were made:

- Houseplants are present in practically all of the participants' homes.
- Women tend to be more interested and experienced in nursing houseplants, and are more prone to have a large number of plants.
- The knowledge about nursing houseplants is rather low, with less differences between men and women.
- Watering is the hardest part of caring for your plants, and doing it regularly seems to be especially hard when lacking a general interest.
- The most common method for watering plants is by doing it as a routine, once or twice a week.
- The main reasons for forgetting to water houseplants is by not having a routine or being stressed and preoccupied.
- The amount of water used when watering is based on intuition for most people.
- Checking if a plant needs watering is mainly done by placing a finger into the soil to check the moisture level.
- Using self-irrigation systems to water houseplants is not common.

Summarizing the conclusions from the survey, the following problem could be identified:

- People in the age group of 18-30 want to have plants in their homes, but those who lack a genuine interest in them tend to fail to give them sufficient care, mainly by forgetting to water them regularly.

3.3 Market research

Having done the research and discovered the issues connected to nursing houseplants, a market research was done in order to further explore what different solutions that are used to make nursing houseplants easier.

The methods and products that were discovered from the survey and the market research were as follows:

- **Watering Can** - placing a filled watering can on visible spot, working as a reminder.

- **Post-it notes** - placing small notes at various places to remind you of watering.

- **Alarm** - Setting an alarm to remind you on specific days.

- **App** - Having an application on your smartphone that works as a reminder, based on information submitted about your plants (Opus Grows, 2018).

- **Digital reminders** - One product was found that measures the moisture level of the soil in a pot, and gives the user feedback (Figure 6). The feedback is given by an LED that changes color depending on the moisture value. Feedback is also given with sound when the soil becomes too dry (PlantRay, 2018).

Figure 6. PlantRay, a digital watering reminder discovered during the market research (Plantray, 2018).

- **Self-irrigation system -** Different systems can be used to continuously add water to plants. These can either be digital or analog. A digital system changes its water drip depending on the moisture level using a moisture sensor (House Logic, 2018). An analogue system is more basic and will add water at a low rate without any electronics (Figure 7). Several different kinds of systems were discovered. Many of them were do-it-yourself projects but a few versions were available on the market.

Figure 7. Example of an analogue self-irrigation system (Smarthome, 2019).

Key findings

- Using reminders like alarms and post-it notes could be a good way of remembering to water your plants. However, most reminders do not provide information of a plant's need for watering. Having a large number of plants might also require you to have several reminders. This was the most popular method after having a routine, according to the survey.
- Using an application to monitor plants could be a good way of giving plants with different needs the correct care. It does require some knowledge and interest to use frequently. However, reminders like these might not get used if the user has a low interest and doesn't want to be reminded too often about watering. None of the participants of the survey used an application as a reminder.
- Self-irrigation systems could be good way of reducing the need for watering, thus benefiting people that often forget to water. This system is also convenient when away from home for longer periods. Having a large number of plants requires a large system or several smaller ones. This could also affect the placement of plants. Having a system like this might not be very decorative as they require you to have small tubes in the plants. Only one of the participants in the survey used this kind of system. Self-irrigation systems might be excessive if you seldom are away from home.
- The product called PlantRay was an interesting device that works as an indicator and was connected to the plant, giving feedback on the moisture level. It is very minimalistic and does not require much effort to use. Using light is an interesting way of increasing the feedback from the plant, as it does not require any interaction with the device, keeping the effort low.

3.4 Triangulation

Analyzing the information gathered in the Discover phase, the following conclusions could be made about houseplants and people’s habits with them:

Based on the survey, basically everyone in the ages 18-30 had plants in their homes. Those who had a genuine interested in them had no trouble nursing them. However, according to the survey, this group was rather small and consists of mostly women. A majority of the participants in the survey had trouble giving their plants the sufficient care, mainly forgetting to water them regularly. Based on information collected during the research, the following three assumptions were made as to why this is:

1. Houseplants do not give much active feedback of their need for watering. It is not until a longer period of having too much or too little water that the plant starts to show signs by wilting. To receive feedback on the moisture level, the best way is to continuously check the state of the soil, either visually or sensing it with your finger.
2. Watering houseplants is something that is done quickly and usually has to be done once or twice a week. It is therefore reasonable to think that it is a concern that is easily overlooked in day to day life.
3. Plants are a part of the interior in a home, and are constantly there for display. This means that they are frequently seen, but not always actively looked at, reflecting if they are in need of watering or not.

Based on the survey, there was a rather large group of people in the ages 18-30 that want plants in their home, but lacks time or interest to learn of their needs and give them the sufficient care. For this group, in order for them to keep having plants without making it into a hobby, they would want the following:

1. Only to think of watering for a brief moment when it is needed.
2. Receive feedback when watering is needed in a way that does not require much effort or attention.
3. Appreciate the benefits of having plants in their home without constantly thinking of their need for watering.
4. Know the correct amount of water needed for a specific plant.

In choosing a solution to proceed with, these assumptions and how well they could be achieved were taken into consideration.

3.5 Making a decision

Based on the insights collected in the Discover phase, together with the assumptions made in the triangulation, a choice was made on what kind of solution the project would focus on. It was decided that the most interesting solution was to make a product that through light visualizes a plant's need for watering, thereby increasing the feedback. This would then hopefully make the nursing of houseplants easier, encouraging people to have more plants in their homes.

As far as the benchmarking went, only one product was discovered that uses light as feedback, and only in a minimal way. It was therefore interesting how this kind of product could be developed further, and in what different ways light could be used as feedback.

4 Define

The purpose of the Define phase was to narrow down what had been discovered in the previous phase, clearly defining the task that for the project. This was done by defining the problem, choosing a target user group, making a persona and setting up a design brief.

4.1.1 The problem

As discovered from the survey, the main problem that the project would focus on was:

- People in the ages of 18-30 want to have plants in their homes, but fail to give them the care needed due to the lack of time, knowledge or interest.

4.1.2 Target user group

With the insights gathered from the survey, the assumption that younger people have a relative low knowledge and struggle to nurse their houseplants seemed to be correct. However, this could also apply to anyone having houseplants, regardless of their age. The target user group for the project was therefore set to:

- People having houseplants in their homes that are having trouble maintaining their health.

4.1.3 Persona

To get a better understanding of who the end-user could be, a persona was created. A persona is a hypothetical individual within the target user group, based on the data collected from potential users (Arvola, 2016).

Kalle

Kalle is 24 years old and lives by himself in a student apartment. He has been studying for two years and just moved into his first apartment after living in a student dorm. Besides putting a lot of effort into his studies, Kalle is active in student activities outside of school and has a rather busy schedule.

He has never put much effort into decorating his home, but now when he has a whole apartment for himself, Kalle wants to make it look nice. Previously Kalle hasn’t had any plants of his own, but when he moved in he received some houseplants from friends and family. Kalle’s knowledge about houseplants is rather low, and so far he has been struggling to keep his plants alive.

Because he spends a lot of time outside the apartment and has a lot going on, Kalle often forgets to water his plants regularly. When he does remember to water them, which can take up to two weeks, he estimates the amount of water the plants need based on their size.

Kalle likes to have plants in his home, as he thinks it makes the apartment look more cozy and relaxing to be in. He wishes he was better at nursing them, but feel like he doesn't have the time nor the genuine interest.

4.1.4 User needs

With the persona in mind, four main user needs could be determined:

- Keep better track of houseplants' need for watering.
- Receive feedback when watering is needed in a way that does not require much effort or attention.
- Appreciate the benefits of having houseplants without constantly thinking of their need for watering.
- Know the correct amount of water needed for a specific plant.

4.1.5 Design Brief

By interpreting the user needs, a design brief could be written to further define the task:

- A product was to be developed that works as an aid when nursing houseplants. This was to be done by using light to increase the feedback received from a plant of its need for watering. The larger goal for the product was to encourage people to have more plants at home without feeling restricted by the lack of time, knowledge or interest.

To further define the task, the following questions were answered:

- What does the product want to be?
- What is the main function of the product?
- How is the product perceived?
- Who is the user?
- What is the personality of the product?
- What is the experience of the product?
- Is the product part of a bigger system?
- What is the technical quality level of the product?
- How does the product affect the environment?

These questions were taught in the course Design Methodology lectured by Per Liljeqvist, lecturer at the Department of Design Sciences at Lund University.

● The product wants to be a helping hand in nursing houseplants.

● The main function of the product is to provide information about a houseplant's access to water, by using light as feedback.

● The product is perceived as fun and innovative.

● The user is someone who enjoys having plants but fail to give them the needed care.

● The personality of the product is eye-catching and encourages usage.

● The experience of using the product is smooth and simple.

● The product is part of a system including plants, indoor gardening and interior decorating.

● The technical quality of the product is advanced on the inside and simple on the outside.

● The product has a small impact on the environment by minimizing components, using sustainable materials and requiring a small amount of electricity to operate.

4.1.6 Mood board

With the help of the design brief, a mood board was made. A mood board aims to visually illustrate what kind of product that is to be developed, in order to give inspiration before going into the Develop phase.

The idea with this mood board was to connect lights, plants and technology.

Figure 8. A mood board connecting lights, plants and technology.

5 Develop

The Develop phase of the project was done in three stages. The first one consisted of testing and evaluating the technical components needed for the solution. These were then used to make simple prototypes used for user testing. Based on the insights gathered from the testing, three concepts for the product could be generated. After evaluating and comparing the three concepts, a decision on the concept to proceed with was made.

5.1 Components

Having defined the task of the project, research was made to discover the different components needed to start the development of a product.

The platform used for electrical prototyping was Arduino, which is an open-source platform based on easy-to-use hardware and software (Arduino, 2019).

5.1.1 **Moisture sensor**

To be able to give feedback of the moisture level in the soil of a plant pot, a component was needed that could get a reading of the moisture level. This could be done by using a sensor. The sensor that was used for testing was a moisture sensor from Luxorparts, designed for Arduino (Figure 9).

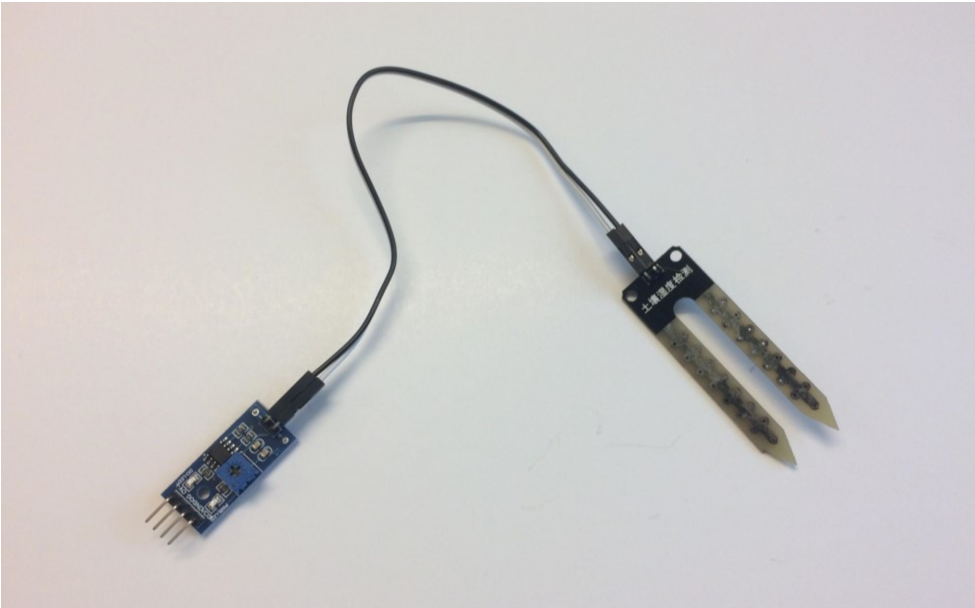


Figure 9. The moisture sensor used for testing.

The sensor is built with two probes acting as a variable resistor, with one probe acting as cathode and the other as an anode. Having water between the probes will make electricity run between them. Depending on the amount of water, the conductivity will vary, and so will the resistance. By measuring the resistance of the two probes, a value can be read, communicating how much water the soil contains (Circuits Today, 2018).

5.1.2 **Light source**

Using the sensor to get a value of the moisture level, the value then had to be used to control a light source. To be able to control the light, an LED pixel was used. The benefit of using an LED is that it is easy to control its behavior in both color and light intensity. An LED also emits a high light intensity while consuming a low amount of energy (AlltomLED, 2017). For this project, an LED called NeoPixel was used (Figure 10). A NeoPixel is an individually addressable RBG color pixel (Adafruit, 2017). RBG stands for red, green and blue, meaning the pixel consists of three LEDs, one for each color. By adjusting the intensity of the three colors, colors on the RGB spectrum can be emitted.

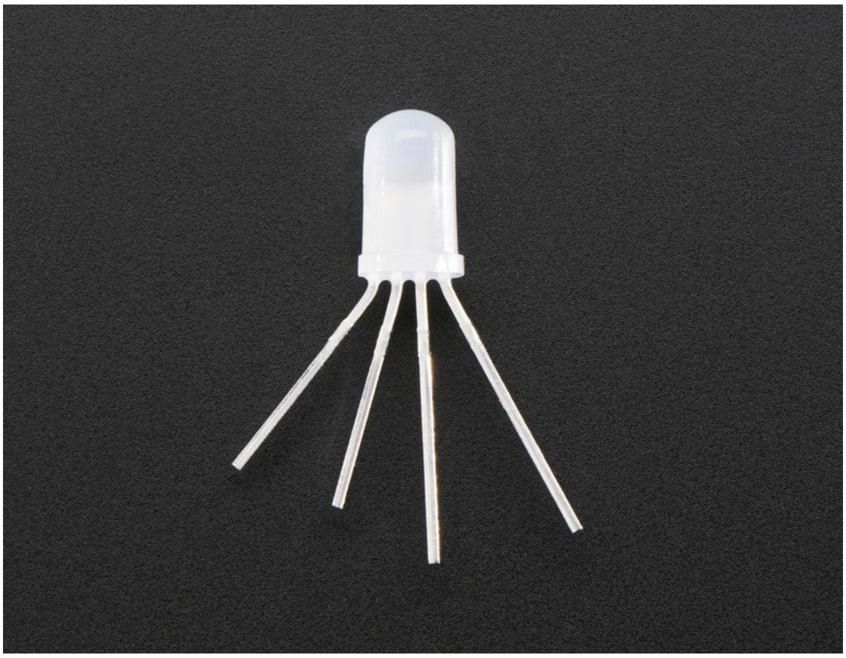


Figure 10. A NeoPixel, the LED pixel used (Adafruit, 2017).

5.1.3 Microcontroller

To be able to connect the value read from the moisture sensor with the NeoPixel, a microcontroller was used, which is a small computer. For this project, three different kinds of microcontrollers were used (Figure 11).

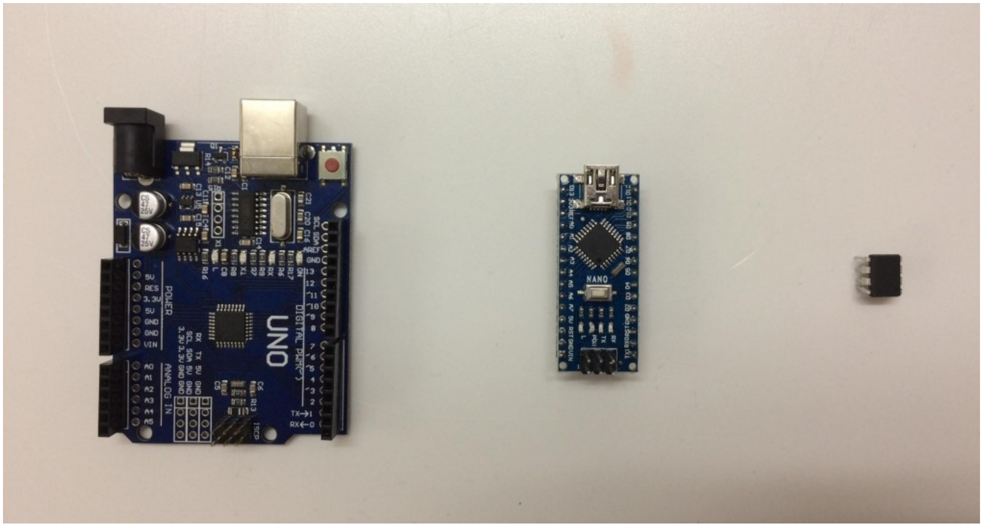


Figure 11. The three different microcontrollers used in the project. From left to right: Arduino Uno, Arduino Nano and ATtiny85.

- **Arduino Uno** - To easily be able to test the components, a microcontroller called Arduino Uno was used.

- **Arduino Nano -** This is a smaller version of the Uno, and was used to scale down the electronics to be able to make smaller prototypes.

- **ATtiny85 -** The ATtiny85 is less powerful and has fewer functions than the other two, but is much smaller. This microcontroller was used in the final prototype.

To program the microcontroller and read the value from the sensor, a software called Arduino IDE was used. This was done by connecting the microcontroller to a laptop via a USB cable (Arduino, 2018).

5.2 Initial testing

The aim of the testing was to discover opportunities and difficulties with the electrical components.

5.2.1 Moisture sensor

To begin testing the sensor, it was connected to an Arduino Uno and tested on a plant. When testing the sensor, a houseplant called China doll was used. This type of plant was used mainly because of it being an average houseplant in regard to its needs, but also because of its size. The plant needs to be somewhat dry between watering, which should be done every three or four days. This made it a good plant to experiment on as the moisture level changes relatively quickly.

Measuring the value

The value being read from the sensor depends on the input voltage. Powering it with 5 V from the Arduino Uno, the value varied from 1023 when without contact with water, to around 200 when fully soaked in water. Changing the input voltage to 3.3 V resulted in values varying between 770 down to 200.

Value change over time

With the sensor placed in the soil, watering the plant quickly decreased the value to around 200. As the water then spreads throughout the soil, the value increases somewhat before settling on a value between 200 and 300.

To study how the value changes over a longer period of time, the value was measured daily for a week after watering the plant. The sensor was powered with 3.3 V. As seen in Figure 12, the value increased linearly, reaching 501 after seven days. By this time, the plant had started to wilt and lose its color.

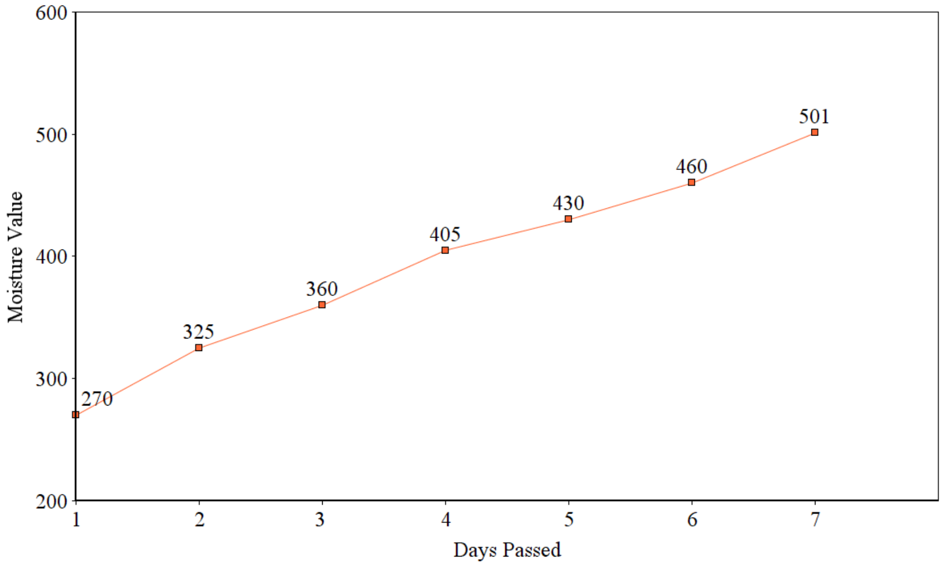


Figure 12. The change over time in moisture value in the soil of a newly watered China doll houseplant. A moisture value of 200 is the maximum while 770 is completely dry.

Placement

When the watering was done by pouring water into a small area in the soil, the moisture level was only increased in parts of the soil, resulting in the sensor only picking up the change if it was placed in the right location.

Corrosion

During the initial testing, no restriction was set to how often the sensor measures the value. Without restricting the measurements, current constantly flows between the two probes on the sensor. This greatly decreases the lifespan of the sensor, making the metal on the probe working as a cathode corrode rapidly. During the first week of testing, the corrosion was already noticeable on one of the probes.

To increase the lifespan of the sensor, the following could be done:

- Using a sensor with a gold plating, providing it with a corrosion-resistant layer.
- Using a sensor that uses capacitive sensing rather than resistive sensing, avoiding the chemical process initiating the corrosion.
- Using the microcontroller to control the sensor, only providing the sensor with power when measurement is required. Some corrosion will still occur as the sensor will be placed in a moist environment, but the lifespan will be greatly increased.

Key Findings

- The sensor worked well to read the moisture value in the soil.
- A consistent voltage supply was needed for the sensor to give a certain range of values.
- Repeatedly inserting the sensor into the soil could possibly damage the root system of a plant if done frequently.
- To make a durable product, corrosion on the sensor would have to be minimized.
- Indicating when the soil contains too much water would probably be possible, but would require further testing on how the moisture value changes over time.

5.2.2 NeoPixel

The initial testing of the NeoPixel was done to discover how easily it could be programmed and how well it could work to communicate the moisture value.

Programming

The light intensity and color of the NeoPixel could easily be programmed by giving the colors red, green and blue a value in light intensity between 0 and 255. By changing the intensity of the three colors, colors on the RGB-spectrum could be programmed (Figure 12).

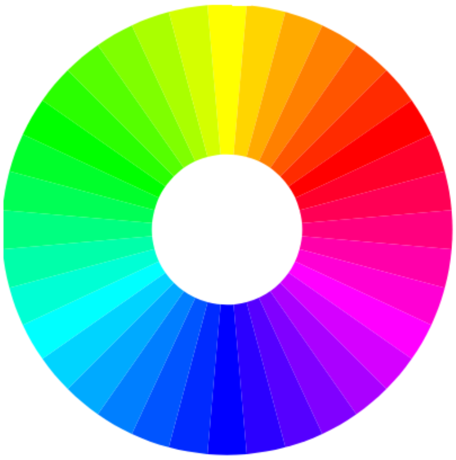


Figure 12. Colors on the RGB-spectrum that could be emitted by a NeoPixel (Wikipedia, 2019).

Light intensity

The light emitted from one NeoPixel at full intensity was bright enough to hurt one's eyes looking at it for too long. To make the light more comfortable, a lamp shade would have to be used. When proceeding in the testing, white paper was used to create simple lamp shades (Figure 13).

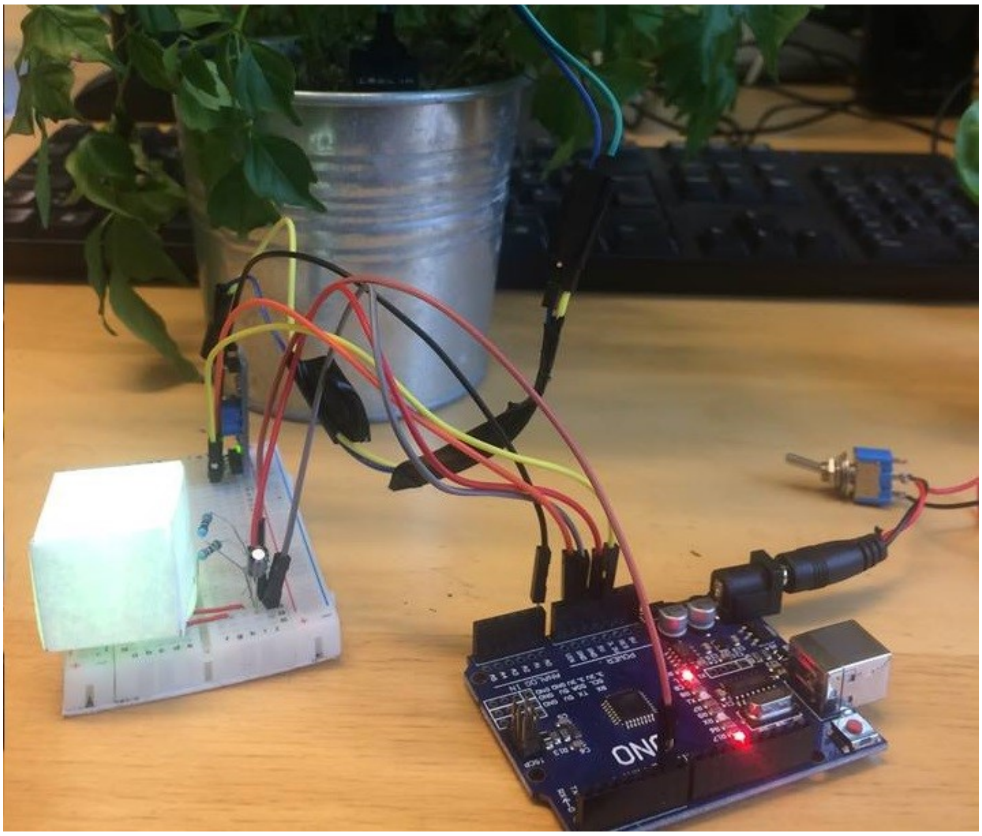


Figure 13. Testing the components. A cube made out of paper was used as a lamp shade for the NeoPixel.

Ways to communicate the moisture level

To use the light to give feedback on the moisture level, different methods could be used. After brainstorming on different solutions, three main methods were chosen:

- Using colors to represent different moisture levels. The most suiting colors to use would be on the spectrum between red and green. Not only are these colors used frequently in everyday life to provide information, they are also the natural colors displayed by some plants and their access to water (Figure 14). Using this method would only require one NeoPixel, but would require a light intensity high enough to be able to communicate the colors in daylight.

Figure 14. Example of how the red and green color scale is used in nature and to provide feedback. Pictures from Unsplash.com.

- Another method was to use light intensity to give feedback. In communicating the moisture level, a high light intensity could represent a high moisture level while a low intensity could represent dry soil. Using this method would require a minimum of one LED, but it could make it more difficult to visualize different moisture levels compared to using color.
- A third method was to use multiple lights to represent a scale. This could be done by having three lit LEDs represent a high moisture level, two represent medium and one being lit represent dry soil. This method would be a simple way of visualizing different moisture levels, but would require multiple lights.

Having evaluated the three methods, it was decided that the most interesting method to proceed with was using color as the way to visualize the moisture level.

Connecting an LED to the sensor

To make the value from the sensor control the color of the NeoPixel, the microcontroller had to convert the value into a color code on the red-green scale. This was done using a simple equation seen in Figure 15. The value is converted by making the light intensity of the green LED increase with an increasing moisture level, and making the red LED increase with a decreasing level. As an example, completely dry soil would give r1 the value 255 and g1 the value 0, resulting in the NeoPixel emitting a clear red color.

```
   val  = analogRead(3);
  int  r1=(val-200)/3.23;
  int  g1=(1023-val)/3.23;

  pixels.setPixelColor(0,  pixels.Color(r1,g1,0));
pixels.show();
```

Figure 15. The method used to convert the moisture value into a color code.

Having implemented the code, the circuit was successfully tested, changing the color of the NeoPixel depending on the value read from the sensor. By updating the value frequently, the whole scale of colors could be seen when slowly inserting the sensor into newly watered soil (Figure 16).

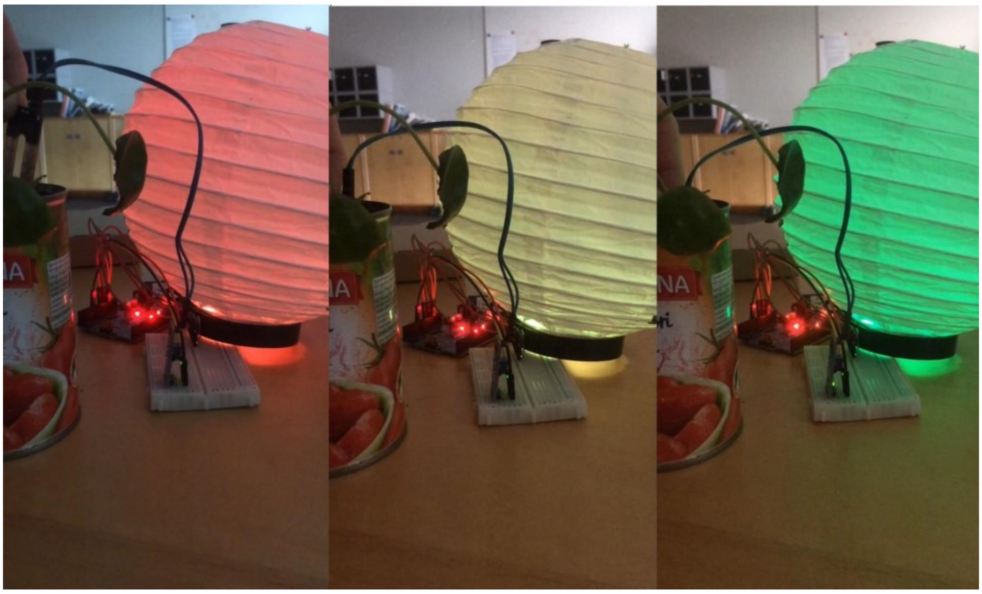


Figure 16. Different colors displayed by the NeoPixel when adjusting the sensor. A paper lantern was used as a lamp shade.

Key findings

- Using a NeoPixel was a simple and energy efficient way of visualizing the value from the sensor. The method used for converting the value worked successfully to display the desired colors.
- Further testing had to be done on how to in the best way match the colors with the moisture value. This would also depend on the plant's needs. The threshold value for in which a plant is in need of watering varies. The code used for converting the value would then have to be changed depending on the plant. Another solution was to use the same code for every plant and instead trust the user to know what color that represents the need for watering for a specific plant. With the current color coding, some plants would need to be watered before the light turns red.
- Using a lamp shade was a good way of making the light more comfortable to look at. The light intensity of a single NeoPixel was bright enough to lit up a paper lantern in a fully lit room.

5.2.3 **Microcontroller**

The testing was done on the ATtiny85, as this was the microcontroller intended to be used in the final prototype.

Sleep mode

To be able to minimize the power consumption, a function in the microcontroller called sleep mode was tested. This deactivates most of its functions when not in use, lowering the power consumption to as low as 0.3μA. By using sleep mode, this could enable the circuit to be powered by a battery and have it last longer.

Controlling the sensor power supply

As the moisture sensor used was sensitive to corrosion, its power supply would have to be controlled to extend its life span. This could be done by powering the sensor from a digital pin on the microcontroller. By programming the pin to deactivate, the sensor could be controlled to shut down in between measurements. During the testing, it was discovered that the sensor only needed to be activated for approximately 10 milliseconds to get a reading from the soil. Using this method, the sensor could be activated in regular intervals, minimizing its use and avoiding corrosion.

Key findings

- The ATtiny85 worked well to power the circuit and was easily programmed. It also had enough output pins to incorporate a sensor, a NeoPixel and a push button.
- Implementing sleep mode worked successfully to greatly decrease the power consumption of the circuit. Depending on how often the product would be used and the amount of power needed, battery could be a viable option. However, it was rather advanced to implement sleep mode into the code, and it would require a lot of time and effort to make it work as intended.
- Controlling the sensor using a digital pin worked as intended and could be used to greatly increase its lifespan.

5.3 Initial user tests

Having tested the components needed for the product, the next step in the Develop phase was to gain insights from users of how well light would work as feedback. This was done by creating lo-fi prototypes of the concept and having users within the target user group use the prototype over a certain period. The focus of these tests was to discover how users interacted with the prototypes, gaining valuable insights on how to further develop the product.

5.3.1 First prototype

The aim of the first prototype was to gain insights on how a potential user's habits of watering their plants would change by having the prototype in their home.

Design

The prototype was made with an Arduino Uno, the moisture sensor used previously and a NeoPixel. The code used was the one that was tested previously, using the red-green color scale to visualize the moisture value.

To power the circuit, a 9 V alkaline battery was attached to the Arduino Uno. A power switch was also implemented between the battery and the microcontroller, to be able to turn the circuit on and off.

A cardboard box was used to cover up the electronics, only showing the relevant parts (Figure 17). The NeoPixel was covered with a small paper cube working as a lamp shade.

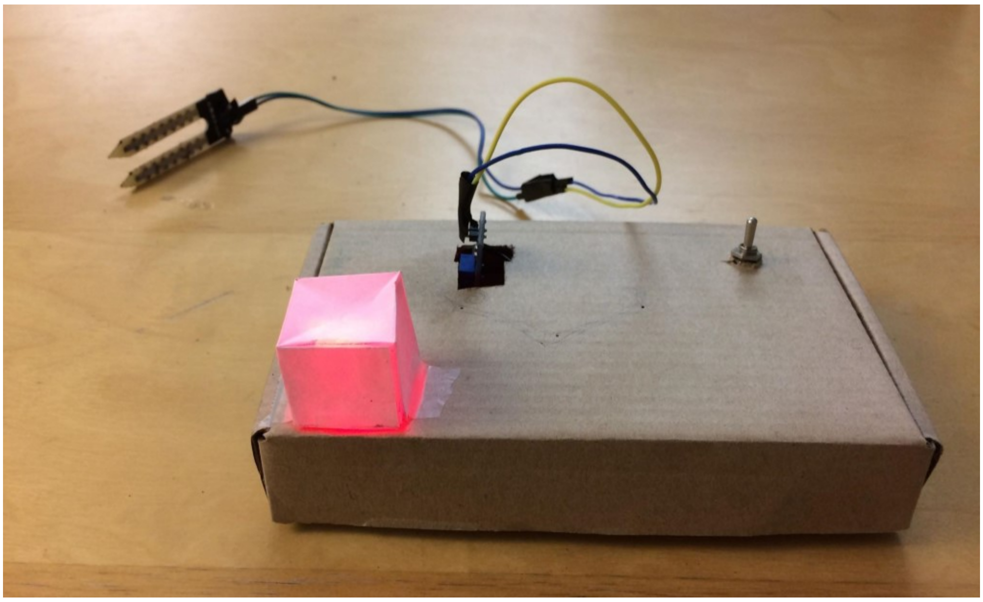


Figure 17. The design of the first prototype.

User test

To test the first prototype, it was handed out to a testee within the target user group to use on a plant in their home for one week. The testee was a 24 year old male living in apartment with 12 houseplants. He had a moderate interest in nursing houseplants and claimed that he had trouble keeping some of them alive.

The testee was given instructions on what the different colors represented and how to put the sensor into the soil. No instructions were given on how often the prototype should be turned on. After a week of testing, the testee was interviewed, with the following result:

- The testee turned on the prototype once every day during the week.
- During the week of testing, the testee watered his plants twice, when the light had turned yellow.
- The testee enjoyed the prototype and stated that it was a more fun way of keeping track of your plants, compared to checking the soil with your finger.
- He liked that the prototype was portable but the size and the length of the sensor cable limited its placement.
- The switch was hard to press.
- The device stopped working after six days due to low battery power.

Key findings

- The device worked successfully as a reminder, making the testee more aware of his plants during the week of testing.
- The color scale worked as intended to communicate the moisture level, and affected the testee's watering habits. However, this did not mean that the plant received the correct amount of water. The plant was watered twice when the color had turned yellow, which might have been too much. The user would have to be aware to the plant's needs, or else the product might cause the plant to be watered too often.
- A portable device made it more flexible for placement. However, using a battery would limit the lifetime of the product.
- As the battery is drained, the voltage output drops, making the code not working as intended. If a battery was to be used, the voltage would have to be kept constant for it to provide the correct feedback.
- The initial user test was in general a success and showed potential in increasing the feedback to affect people's watering habits.

5.3.2 Second prototype

The aim with the second prototype was to continue testing the interaction with users. Another aim was to make a slimmer prototype by decreasing the size of the electronics and make the visual design more appealing. More focus was put on the lighting on the second prototype. As discovered when testing, a single NeoPixel worked well to illuminate a rather large lamp shade. It was therefore interesting in the second prototype to investigate how the product could work both as feedback for the moisture level and as a mood light.

Design

To make the second prototype smaller, an Arduino Nano was used. For this prototype, two NeoPixels were used to see how this would affect the light intensity (Figure 18).

To enhance the lighting of the prototype, the visual design was inspired by a mood light. Cardboard was used to cover the electronics, and a white paper sheet was used as a lamp shade (Figure 19).

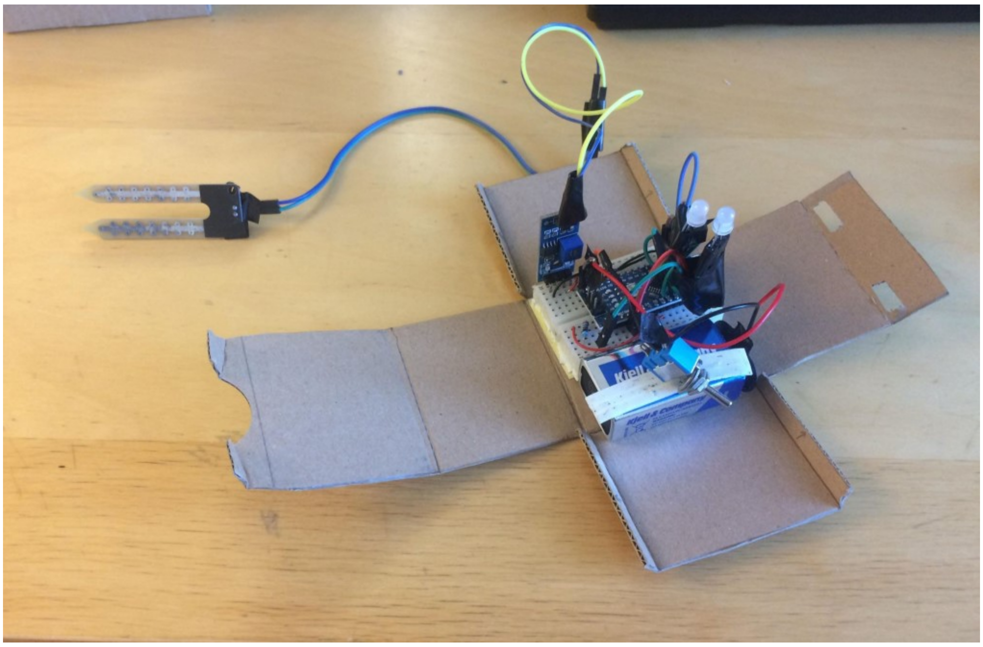


Figure 18. The electronics used for the second prototype, with an Arduino Nano as the microcontroller.

Figure 19. The second prototype, inspired by a mood light.

User test

The second user test was similar to the first one. The testee was a 26 year old male living in an apartment with 10 plants. The same instructions were given to the testee and the test period was one week. For this user test, it was interesting to see how the usage of the prototype changed when the function of a mood light was added. The results from the second user test were as follows:

- The testee turned on the prototype for a few hours every night.
- On the third day of testing, the prototype was left on during the night, fully draining the battery.
- The testee enjoyed having the prototype turned on when it had turned dark outside.
- The testee stated that he became more aware of his plants when using the prototype.

Key findings

- Adding the function of a mood light would affect the usage of the product. Using a battery as a power supply would then be problematic, as the usage would be increased, limiting the life time of the product.
- The function as a mood light was appreciated and could be added as an extra function of the product.
- Using the prototype as a mood light did not seem to affect the main function of providing feedback of the moisture level.
- Adding a second NeoPixel only increased the light intensity slightly.

5.4 Evaluation and further development

At this stage in the development process, valuable insights had been gathered of both the technical possibilities and limitations as well as the interaction design. Some aspects of the product were discovered that had to be discussed further before proceeding in the process.

5.4.1 Feedback

For the product to function as well as possible as a reminder, a high priority would for it to give feedback when it is needed. Having the user manually turn on the prototype worked well for the duration of the first user test. However, manually activating the feedback could become a risk in a longer perspective. As the target user group is likely to forget to water their plants, an issue could be that they eventually also forget to turn on the product, making it lose its purpose.

A solution to this could be to have to product switch on automatically at certain occasions. These occasions could be when the moisture value reaches a threshold, a certain time of the day, or by having a sensor detect when someone is close to the product. The simplest way would be for it to only give feedback when watering is needed. This would keep the feedback to a minimum and avoid it from being excessive. Using the product should not mean that the user should constantly be reminded of their plants' need for watering. Instead, it should aim to be a subtle aid for the user that in its presence works as a reminder but also functions as an indicator of the moisture value. Having the function to automatically communicate feedback was therefore considered a high priority.

However, to be able to implement this function, the sensor would be required to update the value about once every day. A power switch was therefore not a good solution as it would leave the sensor without access to power when switched off. This would also require a power supply that guarantees the product power when it set to turn on automatically.

5.4.2 Varying needs

Another challenge was to make the product usable on plants with varying needs. As discovered in the research, houseplants could be categorized by three types of watering needs - those who have to dry out completely before watering, those who need to be somewhat dry and those who have to be kept moist all the time. The color scale used during the tests would suit the first group best, as the red color represents dry soil. Using the same color scale, the second type would then be in need of watering before the color turns red, more likely yellow or orange. The third type would have to be kept at a green or yellow color.

To incorporate the varying needs of plants, more information had to be stored by either the user or the product itself. One solution was to provide the user with information on which colors represent the need for watering for different plants. This could have been done by making a simple guide that would follow with the product, providing the user with a chart explaining what different colors represent for different plants. This would put more responsibility on the user, but would keep the product simple.

Another solution could be to store more information in the product itself by having different settings. By having the user be able to change the setting, the threshold for when the product turns on automatically could then be adjusted to fit the needs of the specific plant. This would put less responsibility on the user, but would make the product more advanced, increasing the risk of it being used incorrectly.

An argument that was made against making a more advanced product was the ultimate goal for the product. Depending on if the product was meant to make houseplants thrive or merely survive, the need for it to be more advanced would differ. Having only one setting, some plants would perhaps not receive the best care possible, but would still survive.

5.5 Power Supply

An important area that had yet to be evaluated was how the product would be powered. In order to incorporate as many aspects as possible into the decision, the following questions were discussed:

- How often will the product be turned on?
- How much power does the product consume?
- How long would the product last with a battery?
- How does a power chord affect the product?
- Is it possible to supply the product with sufficient power using solar power, and how does this affect the product?

How often would the product be turned on?

Depending on the type of product and its purpose, the usage would vary. By focusing on the function as an indicator, the usage could be minimized as long as enough feedback would be given for it to work successfully. However, as the aim of the product was not only to indicate a low moisture value but to communicate the change over time using the color scale, this would require it to give feedback more often.

The usage would also vary depending on whether the product would be activated manually, automatically or both. By only providing feedback automatically, the usage could be more controlled. However, a risk would then be that the user might not receive the feedback when needed.

With manual activation, the usage would be harder to control, as the probability of the product being left on for longer periods would always exist. Adding the function of a mood light would also increase the usage, and would require it to have a lasting power source. By adding a timer, the usage could still be somewhat controlled even with manual activation.

How much energy does the product consume?

Using a multimeter, the power consumption for the test circuit was measured. With a 5 V adaptor plugged into a wall socket, the circuit consisting of an ATtiny85, the moisture sensor and one NeoPixel consumed:

- 32 mA when the NeoPixel was turned on
- 12 mA when the NeoPixel was turned off
- 1 mA when the NeoPixel and sensor was turned off
- 0.3 μA when in full sleep mode

How long would the product last with a battery?

To power the sensor and the microcontroller, at least 3.3 V was needed. As a reference when calculating battery life, a 3.7 V rechargeable Li-ion battery with 3350 mAh was used, because of its high capacity and small size. The following battery time could be achieved:

- 4 days with the NeoPixel turned on.
- 11 days with the NeoPixel turned off.
- 140 days with the NeoPixel and sensor turned off.
- 1274 years with sleep mode activated.

Using this battery, there were possibilities that the product would be able to function for a longer period. As the majority of the time would be spent in an inactive state, the use of sleep mode could be maximized.

By focusing on the function as an indicator, only giving a limited amount of feedback, the use of the NeoPixel would also be rather low. The power consumption of the sensor could also be minimized as it only has to be activated briefly to be able to update the moisture value.

If the product would be used for lighting, as in a mood light, the battery life would be considerably lower, as the NeoPixel would be turned on longer.

However, the crucial problem with using a battery would be that as the battery is drained, the output voltage would decrease. As the sensor is dependent on a certain voltage to be able to give the same range of values, the product would quickly lose its ability to give the correct feedback, long before the whole battery is drained.

Without a way of keeping the output voltage steady for a long period of time, using a battery as the power source would be problematic.

How does a power cable affect the product?

The best way to guarantee a consistent input voltage was by having the product be connected to a wall socket through a cable. Using a 5 V adaptor, the color scale would then always be accurate and the product would have an unlimited power supply. This would mean the power consumption of the product becomes irrelevant for its life span, which opens up for more functions in the product. It could use more LEDs to give more brightness, or use a motion detector as a power switch. However, having the product connected to a wall socket will affect the placement options and the flexibility. The placement would be limited to areas where a wall socket is within reach. Making a flexible product that could easily be placed next to plants without having to worry about a power cable could be decisive for some users.

A cable would also affect the aesthetics and experience of the product. However, depending where the product is placed, the cable could be more or less hidden.

Is it possible to supply the product with sufficient power using solar power, and how does this affect the product?

Using a solar cell to charge a battery on the product was a possible solution to making it portable while still supplying it with power. However, many questions was raised regarding how this would affect the usage of the product. Adding a solar cell would still affect the placement options, as it would have to be placed at a location exposed to enough sunlight. The fact that the product would be indoors would also affect the amount of power generated in comparison to having it outdoors, as some sunlight is reflected of the window. One advantage of using a solar power was the fact that indoor plants often are placed close to a window, as they also require sunlight. With this in mind, the product would still be flexible as it could be placed close to a majority of the plants in a household.

5.6 Concepts

Having reached a point in the Develop phase where enough testing and evaluations had been made, three concepts could be generated. As the goal was set to be able to implement all functions in the final prototype, the concepts only include components and functions that had been tested previously in the process. All of the three concepts uses the red and green color scale to visualize the moisture value.

When developing the concepts, the focus was on the usage of the product, rather than the visual design. The aim was to make three concepts with different power supplies and usage.

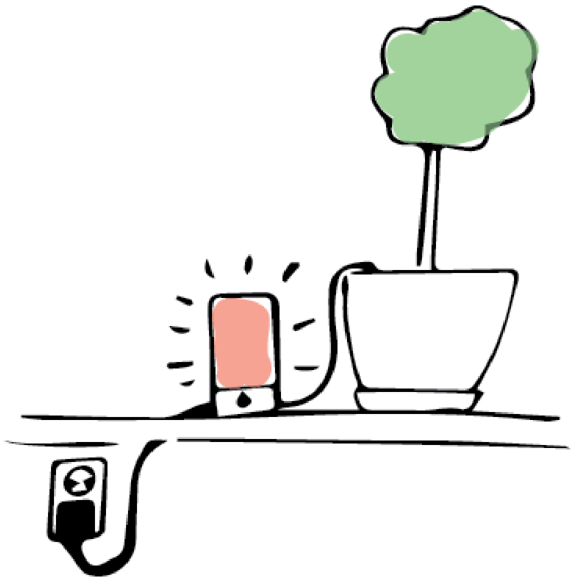
5.6.1 **Concept 1: High usage**

In this concept, the product is a stand-alone device that is placed beside the plant pot. The sensor is connected to the product via a cable.

Its main function is as an indicator/reminder, but it can also be used as a mood light.

It is powered from a wall socket through a cable.

The product is turned on manually, but could also include a timer. When a threshold for the moisture level is reached, the device is turned on automatically until the moisture level rises above the threshold.



As this concept is connected to an unlimited power supply, it could include more functions as power consumption is irrelevant. These functions could be, for instance, adjusting brightness or using sensors for activation.

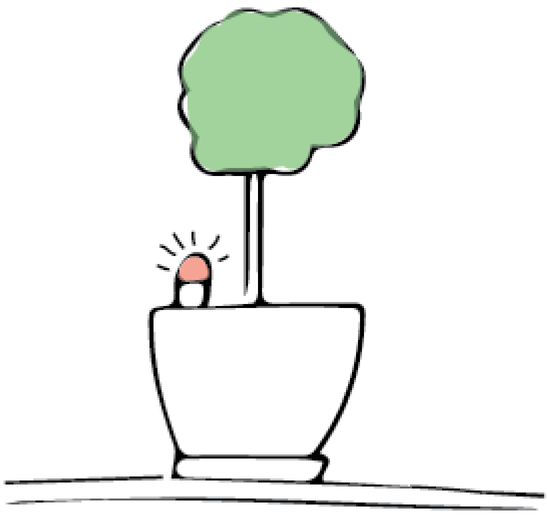
The placement of this concept is limited, as it has to be placed in range of a wall socket. Being a somewhat stationary concept, the idea with this concept is to have one product in a suitable place in your home, and use the feedback as a reminder for watering both the plant it is connected to but also to work as a general reminder to water other plants.

5.6.2 **Concept 2: Low usage**

This concept focuses on the function as an indicator, with a minimized power consumption. The size is also minimized, allowing the whole device to be placed inside the pot.

This concept uses a battery as a power supply. Having a limited power supply, the usage is minimized to make the battery last longer. Feedback is given by manually pressing a button that has to be kept being pressed in order to the LED to light up, preventing it being left on.

When not in use, the microcontroller goes into sleep mode, greatly reducing power consumption. Once every day, the microcontroller is woken up to update the moisture value. When a threshold is reached, the device is woken up every ten minutes, briefly flashing a red light until the moisture value rises above the threshold again.



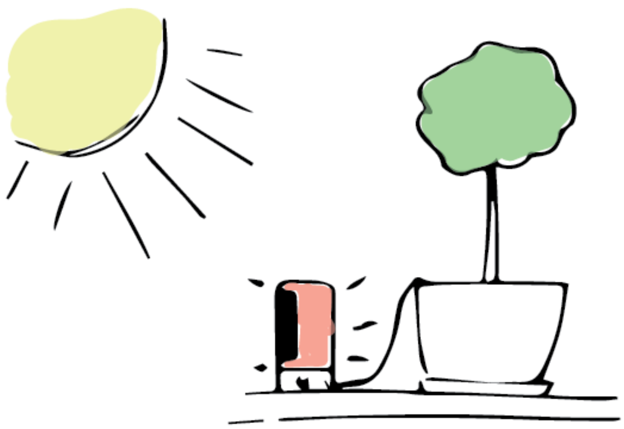
With the low power consumption, the battery is set to last for over a year. When the output voltage from the battery drops too low, a flashing light indicates that a battery change is needed.

Being powered by a battery, this concept is flexible and can be placed anywhere. It can therefore easily be used on different plants regardless their location.

5.6.3 **Concept 3: Medium usage**

This concept is a combination of the two previous concepts, with medium usage.

The device is powered by a battery and uses a solar cell as a power supply. It is therefore being charged during the day, enabling it to be used more than Concept 2. The power consumption still has to be somewhat restricted, as it still can run out of battery. The device can be turned on manually but uses a timer to turn it off when the battery reaches a certain level. It could also use a timer turning it on at certain times during the day.



Using a solar cell as a power supply makes this concept more flexible than Concept 1. However, as the solar cell needs to be exposed to enough sunlight for it to charge, the placement is limited. It would most likely have to be placed next to a window during the day to charge the battery enough. Depending on the energy generated, this concept could go more towards a high usage or a low usage.

5.7 Further user studies

Before making decision on what concept to proceed with, another survey was done to get an understanding of what the user prefers (Appendix B). The aim with the survey was to get feedback on how users would like to use the product.

The survey included a picture of the second prototype, to give the participants an idea of how the light would be used. They were then asked if they preferred to use the product just as an indicator or would like to use it as a mood light as well. They were also asked if they preferred turning on the product manually, having it turn on automatically at specific times or have both functions. Finally, the survey included a question about power supply and whether they would prefer a more flexible product powered by a battery or more stationary one using a power cable. The survey was distributed online and received answers from 20 participants. The following conclusions were made from the survey:

- Two thirds of the participants stated that they would use the product both as an indicator and as a mood light.
- 75% of the participants wanted the product to turn on automatically but also be able to be turned on manually, while 25% preferred only having manual activation. None of the participants wanted the product to only turn on automatically.
- When asked about the power supply, the answers were more evenly split between the options, with a slight advantage for using a power cable compared to using a battery.

Key findings

- By making a stand-alone product that will be placed beside the plant pot, including the function of a mood light would be a way to make the product more appealing to some users. If only used as an indicator, it might feel too large and clumsy for its purpose.
- Considering the results in the survey, it would be necessary to have the product be able to be activated both manually and automatically.
- Regarding the power supply, it was further determined that it would be impossible to choose a concept that would satisfy all users. Some users would prefer a small and flexible product while others would prefer to have it stationary.

5.8 Evaluating the concepts

5.8.1 **Concept 1: High usage**

The largest advantage of this concept is the low maintenance, which was a high priority for the product. Considering the target user group, making a product that could be used without having to worry about battery life could be essential for it to be successful. Using a wall socket as a power supply might not mean a great deal in a longer perspective, as the product is meant to be connected to the same plant for at least a full watering cycle. Even if the placement is limited, plants could be placed next to it rather than the other way around.

Adding the function of a mood light would only be seen as an extra function. As long as it would not affect the products ability to work as an indicator, adding value to the product was an advantage. Having the product powered from a wall socket, this allowed the product to be used without restrictions.

Considering the ability to solve the main problem, this concept has a lot of potential as it guarantees the user that feedback can be provided at all times. The second survey also showed that adding a power cable was preferable for a majority of the participants.

5.8.2 **Concept 2: Low usage**

This concept was interesting as it enables the product to be very small and flexible. It could easily be moved between plants, and might encourage the user to have several of them.

The great disadvantage of this concept was the ability to satisfy the main function. Guaranteeing that the product would be able to give feedback would with this concept be harder to achieve. Because the limited power supply restricts the product's ability to give feedback for longer periods without draining too much battery, the risk of the user not receiving the feedback is increased. As the battery is drained, decreasing output voltage would also be a problem as it makes the product lose its ability to provide the correct feedback. However, with the use of sleep mode, battery life could possibly be extended long enough for it to not be a large issue.

An argument that could be made against this concept was also the fact that it is very similar to the product called PlantRay that was discovered in the market research.

5.8.3 **Concept 3: Medium usage**

This was an interesting concept that, if working as intended, could be an ideal solution. Having the product be portable while still being able to recharge would be interesting as it combines the two other concepts. As with Concept 2, the ability to guarantee the user feedback when needed would still be questionable when using a solar cell as the power source. Responsibility would be have to put on the user to ensure that the battery is charged enough to make the product function.

Taking the time frame of the project into consideration, a great deal of effort would have to be put into experimenting with solar cells to discover if this concept is viable. To keep focus on solving the main problem, this concept was disregarded as it would require too much time to investigate further.

5.9 Choosing a concept

When choosing which concept to proceed with, the definition of the main problem and how it could best be solved was taken in regard. There were pros and cons with all of the three concepts and compromises would have to be made regardless of the choice. The insights gained from potential users throughout the process showed that no concept would satisfy all users.

The choice was made on the concept that was considered having the greatest potential to provide feedback in a reliable and efficient way, while also putting a low responsibility on the user. This description fitted Concept 1 the best. The concept has some disadvantages in limited placement, but it was the most reliable of the three concepts and required no maintenance.

6 Deliver

The deliver phase included the making of a hi-fi prototype of the chosen concept, with the goal to deliver the following:

- *A functional prototype with desired functions implemented*
- *Final user test*

6.1 Concept description

To finalize the chosen concept, a detailed description was made of what the hi-fi prototype would include. The aim with making a final prototype was to be able to communicate the concept as good as possible. To achieve this in a limited amount of time, only the most relevant functions could be included.

The prototype would include the following functions:

- An active state providing the user with feedback of the moisture level.
- A passive state that only provides feedback when the moisture value is too low.
- Push button to switch between the states.

The components needed were:

- ATtiny85
- Moisture Sensor with cable
- NeoPixel
- Push button
- Circuit board
- 5V adapter with cable
- Lamp shade

The prototype would have two states; one active state when the NeoPixel is turned on, and one passive state when it is turned off. In the active state, the sensor measures the value frequently to be able to detect a real-time change of the moisture value. In the passive state, the sensor is turned off to avoid corrosion, but is activated every five seconds to update the value. When the value reaches a lower threshold, the NeoPixel is switched on until the value rises above the threshold again.

6.2 Creating a hi-fi prototype

6.2.1 **Programming**

The following was implemented into the microcontroller:

- The red and green color scale used in previous prototypes, with green representing watered soil and red representing dry soil.
- In the active state, the sensor was programmed to update the value ten times per second, to be able to illustrate the full color scale when using the prototype.
- In the passive state, the use of the sensor was minimized to avoid corrosion. Powering the sensor from a digital pin on the microcontroller, code was implemented so that the sensor is activated for 10 milliseconds every 5 seconds to update the moisture value.
- In the passive state, a threshold value was set for when the prototype would automatically provide feedback.

The full code can be found in Appendix C.

6.2.2 **Circuit board**

To minimize the size of the electronics, the microcontroller was soldered onto a circuit board (Figure 20). A map of the connections is shown in Figure 21.

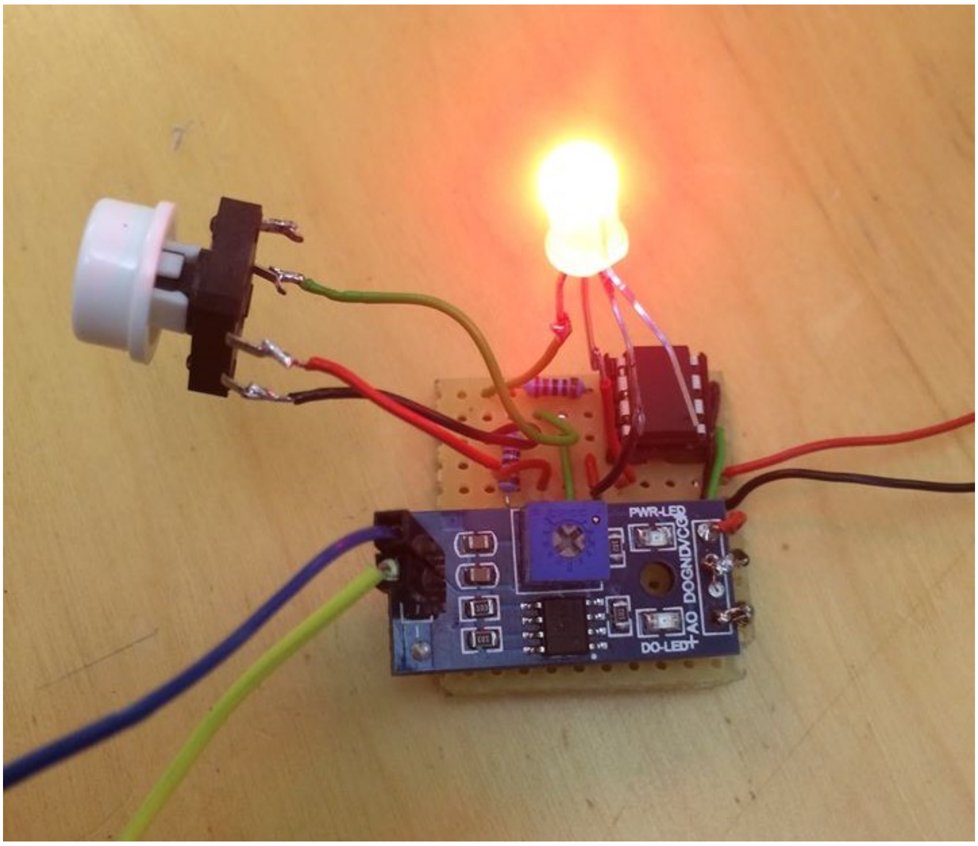


Figure 20. The components soldered onto a circuit board.

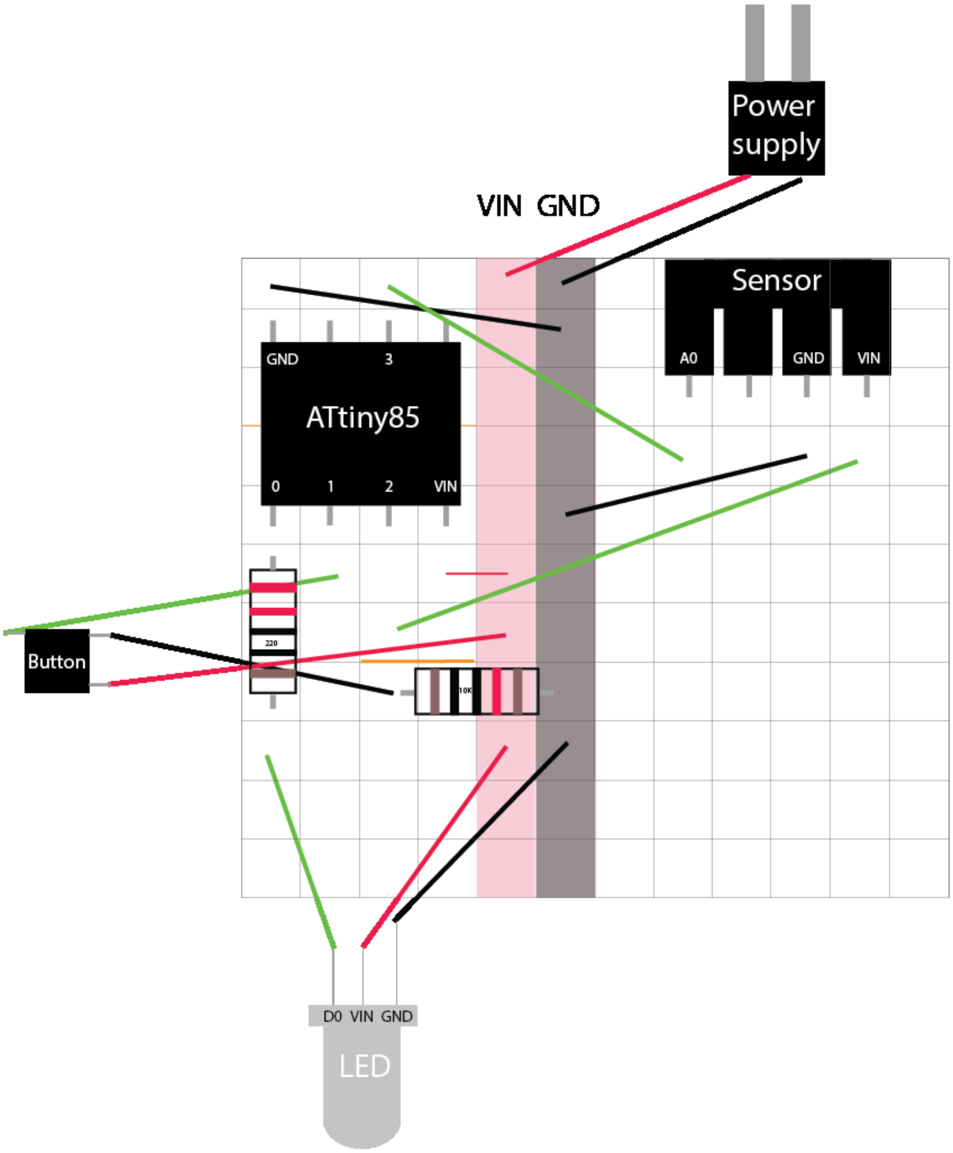


Figure 21. A map of the connections on the circuit board.

6.2.3 **Visual design**

With the size of the circuit board determined, the next step was to decide the visual design of the prototype. The shape and size of the second prototype had been appreciated, which was taken into consideration when designing the final prototype. The requirements for the visual design was that it would have to incorporate a lamp shade and a cover for the electronics. It was also required to have room for a push button that could easily be pressed, and two outlets for the sensor cable and the power cable.

As this concept would be placed beside the plant, it would be visible when not in use. When drawing different alternatives for the shape, the aim was therefore to make a subtle and minimalistic design.

Another aim was to make the prototype be associated with something organic that would go well beside a plant. To make the shape organic while still keeping it minimalistic, the sketches quickly headed towards an oval shape to avoid sharp edges (Figure 22). To distinguish what part of the design that would function as a lamp shade, the shape was made into two parts, where the bottom part would function as a cover for the electronics and not be illuminated. The push button was placed on the front on the bottom part to make it visible and encourage usage. Having a circular cross-section would also enable the button to be used in an ergonomic way, by placing your hand around the product and pushing it with your thumb.

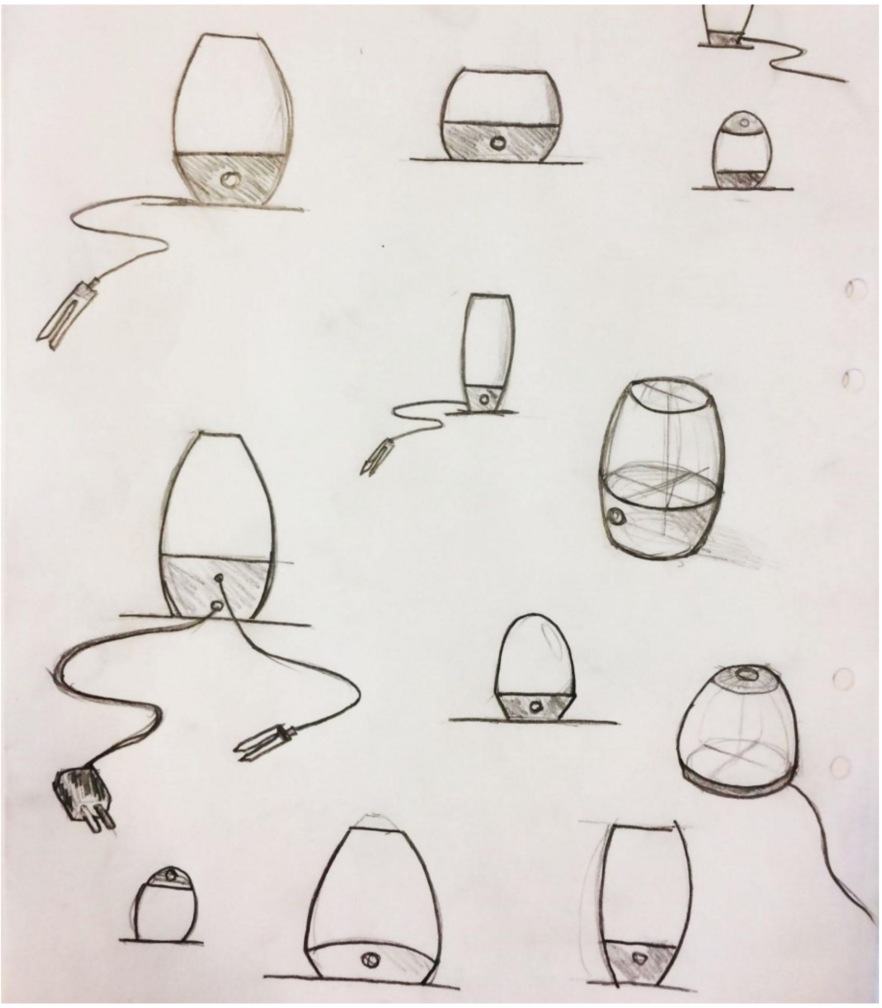


Figure 22. Sketches of the visual design of the prototype.

To be able to manufacture the lamp shade in a fast and cheap way for the final prototype, it was designed to be printed in a desktop 3D-printer. The shape was therefore designed in a way that would enable it to be printed in one piece without the use of support structures (Figure 23).

Figure 23. 3D-model of the top part.

The top part was also required to be made out of a translucent material that would let enough light through to communicate the color. This was done by using white PLA, which is a standard plastic material used for 3D-printing. In a dark room, the PLA produces a diffused, glowing light (Figure 24).

Figure 24. The lamp shade emitting a glowing light in a dark room.

In broad daylight the color is harder to read through the plastic, and the function as a mood light is lost. However, by leaving the top part of the lamp shade open, the color can still be easily read (Figure 25).

Figure 25. In a fully lit room, the color can be easily read by leaving the top open.

To further associate the prototype to nature, the bottom half was manufactured in oak wood using a lathe (Figure 26). Oak was used as it is a rather heavy type of wood, making the prototype more firm.

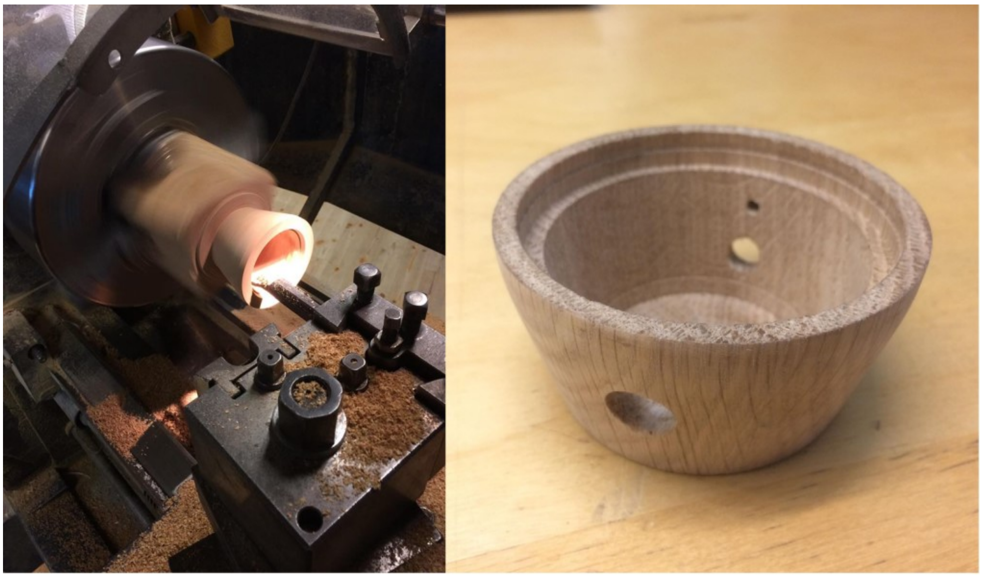


Figure 26. Manufacturing the bottom part in wood.

6.2.4 **Sensor cover**

To make the sensor easier to handle and to protect the top part from moist and dirt, a cover was designed and 3D-printed (Figure 27). A small handle was added on the top of the cover to be able to easily insert and remove the sensor from the soil (Figure 28).

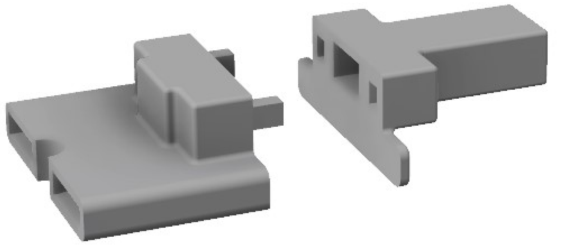


Figure 27. 3D model of the designed sensor cover.

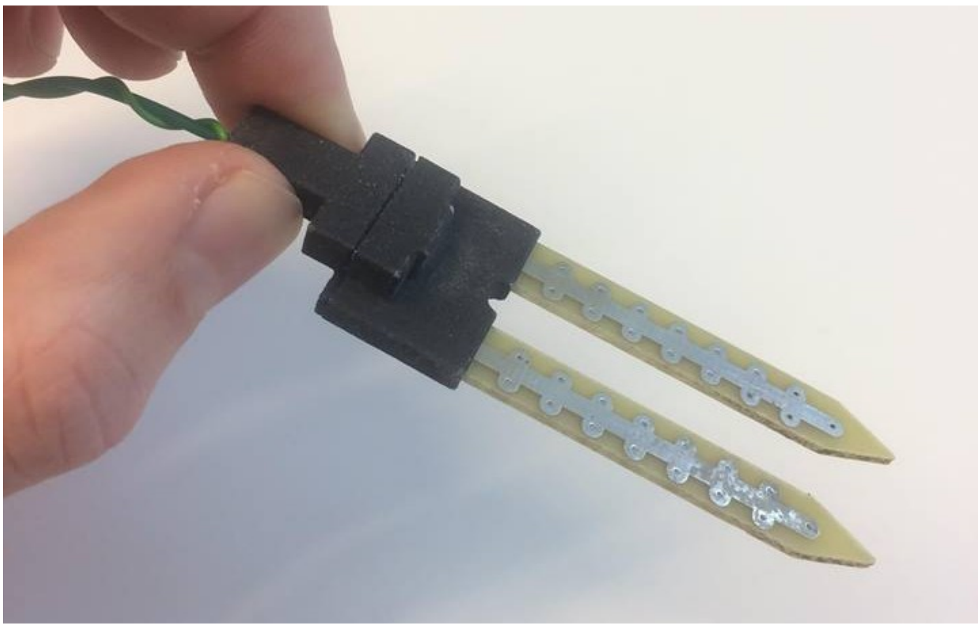


Figure 28. The sensor with the cover applied.

6.2.5 **Attachment mechanism**

As the prototype would consist of two main parts, a solution was needed for how these two would be attached to each other. To find a working mechanism, different alternatives were 3D-printed and tested (Figure 29).

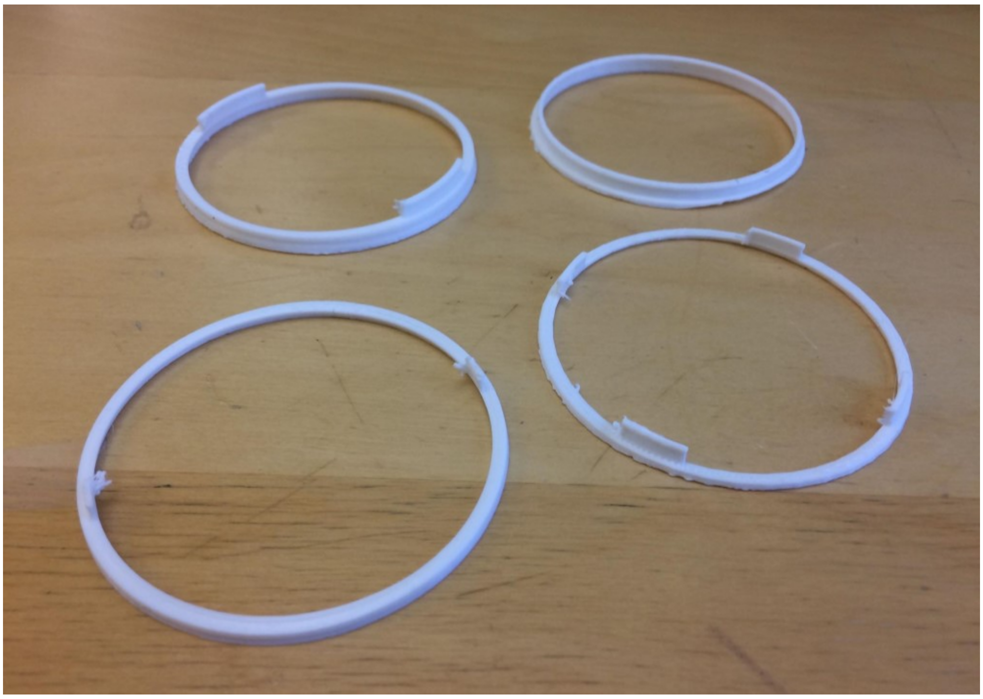


Figure 29. Alternative solutions for the attachment mechanism.

The final solution for the attachment can be seen in Figure 30. When putting the two parts together, the top part snaps into a socket that goes all around the bottom part. By using the mechanism on two opposite sides of the top part, the two parts are easily attached to each other with a force strong enough for its purpose.

Figure 30. A 3D model and a cross-section of the chosen attachment mechanism.

6.2.6 **Full assembly**

To cover the electronics, a lid was made with a hole in the middle to fit the NeoPixel. Finally, a support structure was designed for the push button to be able to be pressed and stay in place. These parts were also manufactured in a desktop 3D-printer. The whole assembly can be seen in Figure 31.

Figure 31. The full assembly of the final prototype.

6.3 Final result

The finished hi-fi prototype can be seen in Figure 32.

The push button is used to switch between the passive and active state.

Figure 32. The finished hi-fi prototype.

The prototype is powered by a cable attached to the back. Placing the sensor into the soil of a plant, the prototype emits a green light upon watering the plant, indicating a high moisture level in the soil (Figure 33).

Figure 33. The prototype emitting a green light to indicate a high moisture level in the soil.

As the plant consumes the water in the soil, the prototype uses the colors seen in Figure 34 to display the change in moisture level. Red represents dry soil.

Figure 34. Colors emitted as the moisture level in the soil decreases.

When in the passive state, the prototype will turn on automatically when the moisture reaches a threshold, emitting a red color to indicate the user that the soil is dry (Figure 35).

Figure 35. Red color indicating a low moisture value in the soil.

6.4 Final user test

To evaluate the final prototype, a final user test was made. The prototype was handed out to at testee during a week. The aim of this user test was mainly to get feedback on the visual design of the prototype and how it would be used. The testee was given instructions on what the colors represented and how the active and passive state worked. The results from the final user test were as follows:

- The power cable made it hard for the product to stay in a desired position, as the product is rather lightweight.
- The testee thought the sensor cable was too stiff, making it hard to hide when placed in a pot.
- The push button worked well and was easily pressed.
- The cover on the sensor worked well as a grip when handling the sensor. However, the testee would have wanted a more ergonomic shape on the handle.
- The sensor was easily placed in most pots, but it was harder to insert the whole sensor in pots with plants having a large root system.
- The testee would have wanted a cover on the top, so that the NeoPixel would not be seen when looking from above.
- The visual design of the product was appreciated, and the testee thought the size was good as it does not take up too much space.
- The testee liked the glow the product produces in dark room. However, he would have preferred a higher light intensity in a lit room.
- The testee used the product most days during the test week, turning it on on evenings.

Key findings

- The prototype would have needed more weight in order to stay in place and not be too affected by the power cable.
- The grip on the sensor could be designed to be more ergonomic.
- The sensor cable could be made less stiff, to be able to hide it easier.
- The sensor would have to be made smaller to be able to be placed in all kinds of pots.

6.5 Manufacturing costs

As the electrical components used in the final prototype were purchased individually, the total cost was rather high. The cost for manufacturing the top and bottom part was low as they could be made with the resources available at Ingvar Kamprad Design Center. The total cost of the electrical components used in the final prototype were as follows:

- Sensor: 80 SEK
- Microcontroller: 30 SEK
- RGB LED: 10 SEK
- 5V adapter: 120 SEK
- Wires, circuit board etc.: 20 SEK

Total: 280 SEK

If these parts are purchased in greater quantities from a larger electronics supplier, the cost of the electrical components can be estimated to:

- Sensor: 5 SEK
- Microcontroller: 10 SEK
- RGB LED: 5 SEK
- 5V adapter: 20 SEK
- Wires, circuit board etc.: 10 SEK

Total: 50 SEK

Accordingly, the cost of the electrical components can be greatly reduced when purchased in greater quantities. However, the cost would be even lower if the product was made by a company as this estimation was done when purchasing the components as an individual.

As the final prototype was made without taking manufacturing costs into consideration, the total cost of the product would much depend on the choice of distribution and materials used for the visual design, further discussed in the conclusion.

7 Discussion and conclusion

7.1 Methodology

Using the Double Diamond design process proved to be very suiting for this type of project. As the project was carried out trying to solve a problem rather than having a specific product in mind, using this method enabled the work to stay open-minded. Each of the four phases were kept rather open to what they should contain, giving a lot of freedom to experiment within each phase.

As the result was a concept for a consumer product, user-centered design was made an important part of the project. Therefore, the need for user input was important throughout the development. An advantage in this project was the large group of potential users. In many cases, useful insights could be gathered by consulting friends, family and fellow thesis workers. The surveys that were done also gave a lot of useful insights, and showed that it would be impossible to make a product that would satisfy all.

In retrospective, additional user tests could have been done with the earlier prototypes. Testing them for longer periods of time would have given better insights on how they affect the watering habits of the user.

Even though the process contained many smaller iterations, the develop phase had to be kept straight forward to follow the time schedule. Rather than testing a wide range of different possibilities and concepts, more focus was put on evaluating and motivating the different choices that was made.

7.2 Time management

As this thesis was written by one person, this had to be taken into consideration during the work process. The advantage of working alone was that many decisions could be made quickly and less time was spent organizing the work. A disadvantage was on the other hand that some of the parts of the process took longer than expected, most notably the Develop phase. A lot of time had to be spent researching and testing the hardware and software components used in the project, as my previous knowledge was limited. This was also a consequence of the goal set to be able to implement the solutions discovered.

During the process, I became more and more aware of the amount of time needed to develop a new type of product. It was therefore important that the time frame was followed for the four stages on the process, to be able to achieve the goal set for the project. The most difficult part was to keep the Develop phase within the time frame and be able to incorporate all of the aspects of the product. Throughout this phase, compromises had to be made in order avoid spending too much time on a specific area.

Considering the scope of the thesis and the circumstances for which it was carried out, the time management was satisfactory. The initial time schedule and the outcome is seen in Figure 36 and Figure 37.

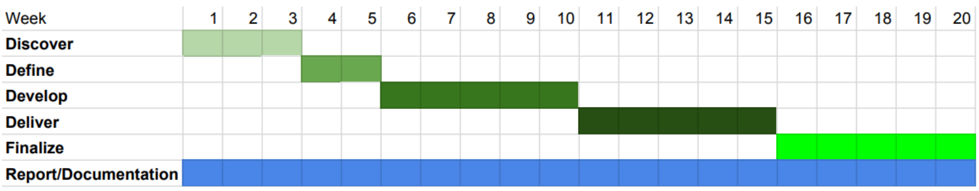


Figure 36. Initial time schedule for the project.

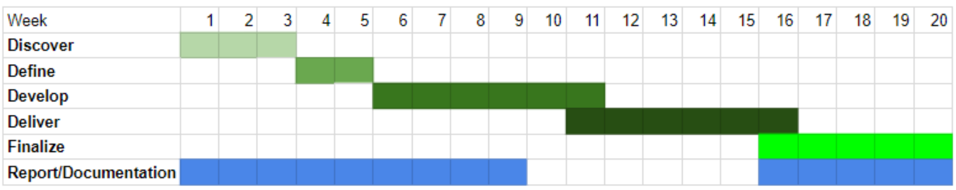


Figure 37. Outcome of the time schedule for the project.

7.3 Concept and prototype

The design process resulted in a concept and a prototype that shows good potential of being a helpful product in the nursing of houseplants. Even though the result is far from being a finished product, the concept of using light to enhance the feedback from plants is an interesting solution. During the user tests, the prototypes showed this type of product could have a positive impact on users' watering habits. This project could therefore be seen as a study on how such a product could be developed, rather than a concept for a finished product.

In regard to my technical knowledge and the time frame of this project, the final prototype that was made was sufficient to be able to illustrate its purpose and potential.

Adding the function of a mood light could make the product more appealing. During the user tests, this was appreciated and added more value the product. Using 3D-printed PLA as the material for the lamp shade also proved to be a working solution, producing a diffused glow.

7.4 Production and pricing

As no goal on distribution and production was set for the project, this was not taken into consideration when making the final prototype. The aim of the final prototype was rather to illustrate the functions and possibilities of the product. The choice of materials and manufacturing methods were therefore based on how easily the parts could be made and how they could make the prototype appear more like a finished product. As a consequence of this, the methods and materials used for manufacturing the top and bottom part would not have been fitting if the product is meant to be produced in greater quantities.

When taking distribution into consideration, three main alternatives for the product are possible:

- Making it an open-source product that users can make themselves. This could be done by providing instructions on how the concept works, including coding, the electrical circuit and the possibilities and challenges that were discovered along the way. These instructions could for instance be posted to an online forum for Arduino projects. By making it into a do-it-yourself project, the user could customize the product in both function and in visual design.

- Having it be exclusive and niche, focusing on the presentation and feel of the product rather than the production cost. This alternative would be the most fitting with the current design of the prototype, as the wooden part would be expensive to manufacture in greater quantities. The top part could for example be made out of frosted glass rather than plastic, as the quality of the 3D-printed top part was rather low. Using these materials, the total price for the product will probably be around 300-500 SEK.

- Focusing on production costs by choosing materials and manufacturing methods that enables the product to be made in large quantities to a low cost. The cheapest method would most likely be to design the main parts for injection molding in plastic. Based on the estimated costs of the electrical components, the total cost of the product can then be reduced to 100-150 SEK.

As this project was done individually without connection to a company, the most reasonable choice would be to make the concept an open-source project. However, with the hi-fi prototype made, it can be used to pitch the product to companies that could be interested in further developing the concept. As the market research showed, it appears that this type of product is rather unique and is without many competitors, which opens up possibilities for it to become profitable.

7.5 Further development

As the final prototype only included the essential functions, a lot of further development could be done. Many functions and alternative solutions were discovered along the way that would have been interesting to investigate further and test on users.

7.5.1 **Moisture sensor**

When programming the color scale, the colors that was used in the prototype to represent different moisture values were only studied briefly. In further developing the product, the need to investigate what moisture values that best represent sufficiently watered soil and dry soil would be required. The threshold used in the prototype for when feedback is automatically given was set rather arbitrary to a value that was somewhat dry.

7.5.2 **Varying needs**

To account for the different watering needs for different plants, it would have been interesting to implement different settings. By adding a button that switches between settings, the product could be set to match a plant's specific needs, changing either the threshold or the whole color scale.

7.5.3 **Indicate over-watering**

One function that was never tested was to indicate when the soil contains too much water. This could have been done by further researching how the moisture value changes when the soil is newly watered. By programming the microcontroller to give feedback when the soil remains at high moisture value for too long, this function could be implemented.

7.5.4 **Interaction design**

It would be interesting to further research how users' watering habits could be changed with this type of product. Would one be enough to work as reminder for other plants as well, or would some users want to have several connected to different plants? How would users react to having a timer on the product, giving feedback for a brief moment every day? To research this, user studies over longer periods would have to be made.

7.5.5 **Battery**

To make a product that could easily be moved between plants, it would have to be powered by a battery. By implementing sleep mode and thus minimizing the power consumption, it would be interesting to investigate how long the product could last. However, as discussed previously, it would require the battery to be able to sustain the same output voltage in order for the code to function properly.

7.5.6 **Solar cell**

Powering the product with a solar cell was an option that I would have wanted to investigate further, but would have required too much time. This would have made the product even more innovative and unique.

7.5.7 **Sensor**

The sensor used for the final prototype is made for Arduino. The technology used to measure the moisture value is not very advanced. If developed further, a new and smaller sensor could have been developed as the one that was used tended to damage the root system when on smaller plants.

References

Adafruit. The Magic of NeoPixels. Retrieved January 3, 2019 from https://learn.adafruit.com/adafruit-neopixel-uberguide/the-magic-of-neopixels

AlltomLED. LED och miljö. Retrieved January 3, 2019 from http://www.alltomled.se/guider/led-miljo/

Arduino. Software. Retrieved January 3, 2019 from https://www.arduino.cc/en/main/software

Arduino. What is Arduino? Retrieved January 3, 2019 from https://www.arduino.cc/en/Guide/Introduction

Arvola, Mattias. 2016. *Interaktionsdesign och UX – om att skapa en god användarupplevelse*. 3rd ed. Lund, Sweden: Studentlitteratur.

BiologyWise. How is Photosynthesis Related to Cellular Respiration. Retrieved on January 4, 2019 from https://biologywise.com/how-is-photosynthesis-related-to-cellular-respiration

Circuits Today. Arduino and Soil Moisture Sensor - Interfacing tutorial. Retrieved January 3, 2019 from http://www.circuitstoday.com/arduino-soil-moisture-sensor

Design Council. The Design Process: What is the Double Diamond? Retrieved January 3, 2019 from https://www.designcouncil.org.uk/news-opinion/design-process-what-double-diamond

Dictionary.com. Autotroph. Retrieved January 8, 2019 from https://www.dictionary.com/browse/autotroph

Ewert A, Chang Y (2018). *Levels of Nature and Stress Response. Bloomington.* United States: Indiana University.

Folkhälsomyndigheten (2018). Statistik över vuxnas psykiska hälsa. Retrieved January 3, 2019 from https://www.folkhalsomyndigheten.se/livsvillkor-levnadsvanor/psykisk-halsa-och-suicidprevention/statistik-psykisk-halsa/vuxnas-psykiska-halsa/

Houselogic. 5 Ways to Automatically Water Your Plants When You're Gone. Retrieved January 3, 2019 from https://www.houselogic.com/by-room/yard-patio/how-to-water-plants-while-on-vacation/

Nationalencyklopedin. Autotrofi. Retrieved on January 6, 2019 from https://www.ne.se/uppslagsverk/encyklopedi/l%C3%A5ng/autotrofi

Nationalencyklopedin. Fotosyntes. Retrieved on January 6, 2019 from https://www.ne.se/uppslagsverk/encyklopedi/l%C3%A5ng/fotosyntes

Opus Grows. 5 Apps that will (kinda) guarantee you won't kill your houseplants. Retrieved January 3, 2019 from https://www.opusgrows.com/blogs/journal/108690758-5-apps-that-will-kinda-guarantee-you-won-t-kill-your-houseplants

Plantagen. Vattna dina krukväxter inomhus - så lyckas du. Retrieved January 3, 2019 from https://www.plantagen.se/vattna-dina-krukvaxer-inomhus-sa-lyckas-du

Planet Natural. Indoor Plant Care. Retrieved January 6, 2019 from https://www.planetnatural.com/plant-care/

Plantray. The Smart Plant Watering Reminder. Retrieved January 3, 2019 from https://www.plantray.com/

Smarthome. Claber Oasis Automatic Watering System. Retrieved January 4, 2019 from https://www.smarthome.com/claber-8053-oasis-self-watering-system.html

Sundquist K, Frank G, Sundquist J. (2004). *Urbanisation and incidence of psychosis and depression: follow up study of 4.4 million women and men* in Sweden. Stockholm, Sweden: Karolinska Institutet.

The Royal Horticultural Society (RHC). Houseplants: to support human health. Retrieved January 3, 2019 from https://www.rhs.org.uk/advice/profile?PID=949

Time. You Asked: Can Indoor Plants Really Purify The Air? Retrieved January 7, 2019 from http://time.com/5105027/indoor-plants-air-quality/

United Nations. (2018). 2018 Revision of World Urbanization Prospects. Retrieved January 3, 2019 from https://www.un.org/development/desa/publications/2018-revision-of-world-urbanization-prospects.html

United States Environmental Protection Agency. Indoor Air Quality. Retrieved on January 6, 2019 from https://www.epa.gov/report-environment/indoor-air-quality

Wikipedia. Fil: RGB Color Wheel 36.svg. Retrieved January 4 2019, from https://sv.wikipedia.org/wiki/Fil:RGB_color_wheel_36.svg

Appendix A: Survey 1

Generellt om inomhusväxter

Kön, ålder och boendeform.

Ditt svar

Hur intresserad är du av inomhusväxter och skötseln av dom?

1	2	3	4	5
○	○	○	○	○

Hur bra är din kunskap om inomhusväxter och skötseln av dom?

1	2	3	4	5
○	○	○	○	○

Hur många växter har du i din bostad? Om inga, varför?

Ditt svar

Vad är de största skälen till att du har växter hemma?

Ditt svar

Vad är det jobbigaste med att ha växter hemma?

Ditt svar

Vad gör du för att komma ihåg att vattna dina växter?

Ditt svar

Om du ofta glömmer bort att vattna dina växter, vad beror det på?

Ditt svar

Hur lång tid kan det gå utan att du vattnar?

Ditt svar

Hur ofta kollar du om en växt behöver vattnas?

Ditt svar

Hur avgör du hur mycket vatten olika växter behöver?

Ditt svar

How would you rate your knowledge on the needs of different different kinds of houseplants?

1	2	3	4	5
○	○	○	○	○

Hur avgör du om du vattnar en växt fel?

Ditt svar

Har du köpt dina växter själv eller fått dom på annat sätt?

Ditt svar

Appendix B: Survey 2

Växtlampa

Du har en lampa hemma som genom färg visar fuktnivån i en kruka, vars syfte är att påminna dig om dina växters behov av vattning. När jorden är vattnad lyser lampan grönt och går sedan i en färgskala från gult till orange och slutligen rött när jorden är torr.

Lampan lyser med ett ljus som bilden visar. Skulle du:

- ◯ Bara använda lampan som indikator för att ta reda på växtens behov av vattning.
- ◯ Använda lampan även för belysningens skull.

Du skulle helst vilja:

- ◯ Tända lampan manuellt för att få information om fukthalten.
- ◯ Att lampan tänds på automatiskt under en viss tid på dygnet.
- ◯ Att lampan tänds automatiskt men att den även kan tändas manuellt.

För att driva lampan kan antingen ett batteri användas eller en kabel kopplad till ett vägguttag. Föredrar du att:

- ◯ Lampan drivs på batteri som måste bytas ut/laddas en gång i månaden (om den används en timme per dag), vilket ökar underhållet men gör att den kan placeras var som helst.
- ◯ Lampan är kopplad till ett eluttag vilket gör den underhållsfri men begränsar placeringen.

Andra förslag eller tankar:

Ditt svar

Appendix C: Arduino Code

```
#include   <Adafruit_NeoPixel.h>
#ifdef __AVR__
   #include  <avr/power.h>
#endif

#define PIN             0
#define NUMPIXELS       1

Adafruit_NeoPixel  pixels  =  Adafruit_NeoPixel(NUMPIXELS,  PIN,  NEO_RGB  +  NEO_KHZ800);

int delayval = 500; // delay for half a second
const int nMos = 2;
int count = 0;
bool mode = false;
int val;
int j = 99;
int k;
void setup() {
   pixels.begin();
   pinMode(nMos,  OUTPUT);

}

void loop() {
j++;

if(j == 100) {
digitalWrite(nMos, HIGH);
delay(100);

val  =  analogRead(3);

j = 0;
digitalWrite(nMos, LOW);
}

delay(100);


if(val>900){
    pixels.setPixelColor(0,  pixels.Color(255,0,0));
   pixels.show();
   delay(10);
}
else{
    pixels.setPixelColor(0,  pixels.Color(0,0,0));
   pixels.show();
   delay(10);
}
```

```
 if(digitalRead(1)== HIGH && mode == false) {

mode = true;

   digitalWrite(nMos, HIGH);
 delay(100);
  val = analogRead(3);
  delay(10);
   digitalWrite(nMos, LOW);

   if(val<350){
       pixels.setPixelColor(0, pixels.Color(0,255,0));
      pixels.show();
      delay(100);
   }
   else{
    int r1=(val-200)/3.23;
    int g1=(1023-val)/3.23;

    pixels.setPixelColor(0, pixels.Color(r1,g1,0));
  pixels.show();
  delay(100);
   }

 while(mode = true){





  if(digitalRead(1) == LOW && mode == true) {
    count = 1;
  }


     if(digitalRead(1) == HIGH && count == 1) {
      mode = false;
      delay(100);

      count = 0;
      j = 99;
    }

}
```