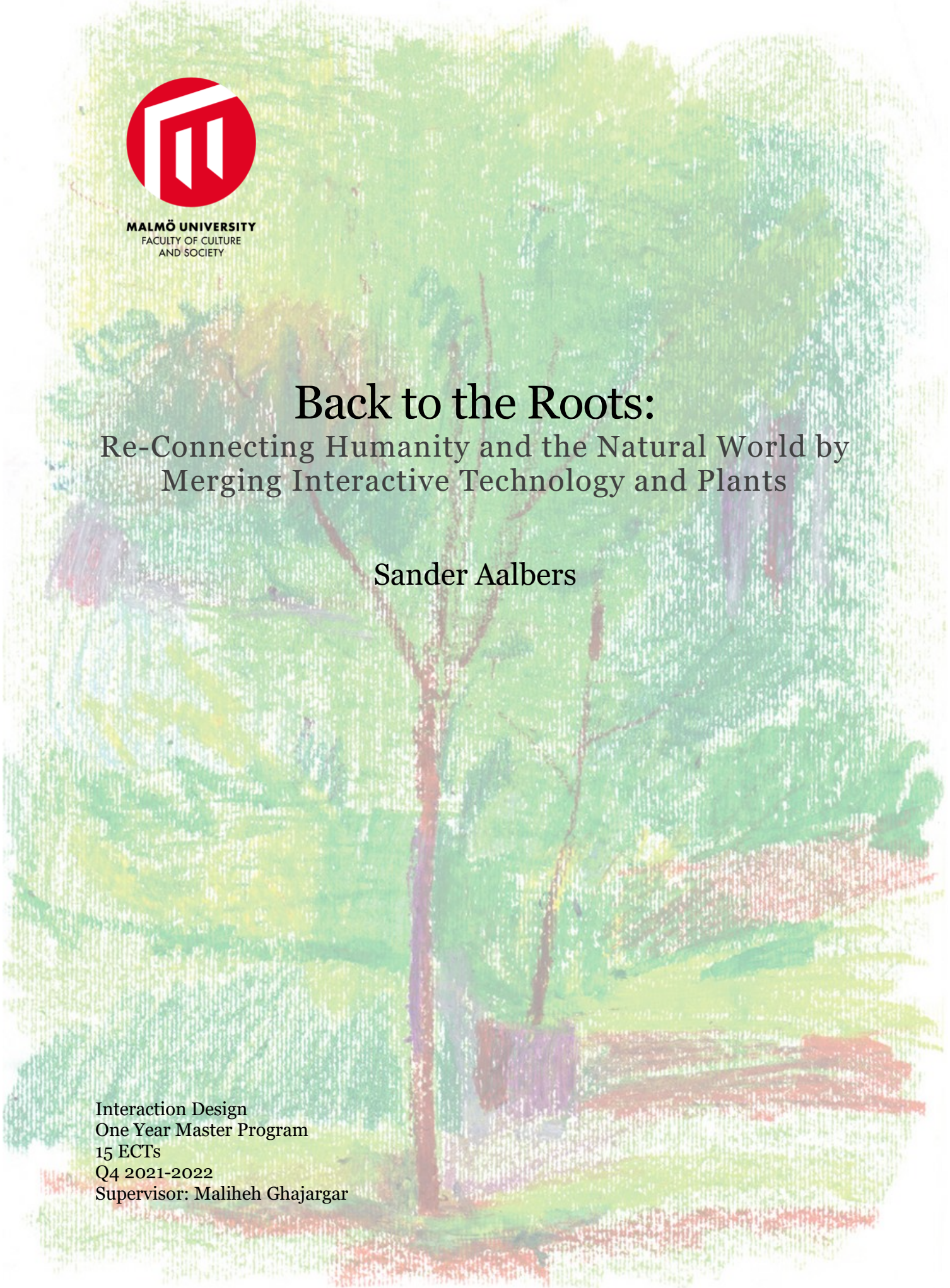

MALMÖ UNIVERSITY
FACULTY OF CULTURE
AND SOCIETY

Back to the Roots:

Re-Connecting Humanity and the Natural World by Merging Interactive Technology and Plants

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“In ancient times, the land
lay covered in forests,
where from ages long past,
dwelt the spirits of the gods.
Back then, man and beast
lived in harmony,
but as time went by, most
of the great forests were destroyed.”

Princess Mononoke (1997)

The drawing shown on the cover of this thesis is made for and first published in the book Growing by Darko Aleksovski, published by PrivatePrint, Skopje, 2016

ABSTRACT

This thesis project explores combining interactive technology and the natural world, through a more-than-human design approach. This project aims to step away from an industry-driven design by valuing plants as equal in the design process. Throughout this report, an overview of the relevant theory and examples are elaborated on. This overview has informed the project in two ways. It formed the foundation of a concept aiming to improve the user's interconnectedness with nature and it formed the foundation of an evaluation tool developed for aiding designers in design for plants by addressing three design fields: *Design for Care, Design for Cohabitation,* and *Design for Noticing.* The concept and the evaluation tool have been developed in parallel and informed each other throughout the project. The final concept contributes to the discussion about addressing more-than-human actors in design. In this case by addressing plant blindness. The evaluation tool contributes to more-than-human design as a tool to evaluate ideas and projects. This project included an extensive analysis of a design collection, workshops regarding the materiality of living plants and assessment of the evaluation tool, an interdisciplinary design approach, and a prototyping phase during which assumptions regarding the concept were tested.

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1. INTRODUCTION: AIM AND RESEARCH DIRECTION

In recent years the ecological crisis has become ever more pressing, which has led to a multitude of scientists across different research disciplines advocating for action (Smith, 2017; Forlando, 2016), including Human-Computer Interaction and Interaction Design (Dunne & Raby, 2013). Within the field of Interaction Design special interest is found in the manner of conduct that is prevalent.
Traditionally, design disciplines such as Industrial Design, Product Design, and Interaction Design are built on serving three main pillars: *People, Technology,* and *Organization* (*Industrial Design Engineering Programme*, n.d.; *Interaction Design | Malmö University*, n.d.). Different words are used across disciplines however most of them can be boiled down to a similar constellation. *People* refers to the ergonomics, usability, and desire for products, *Technology* refers to the feasibility of products and *Organization* refers to the viability of marketing the product. Bardzell et al. (2021) note that in the past HCI, as well, has taken mainly industry pursuits into consideration. Ultimately this puts the human at the center of Design, creating a human-centered design practice, this means that ecological concerns cannot be adequately addressed (Wendt, 2017) and more-than-human voices cannot be accounted for (Akama et al.; 2020, Forlando, 2017). Here more-than-human voices refer to other than human actors within the context of the project. According to Bardzell this inevitably leads to a dichotomy; the notion that designers are expected to look at the world in a designerly manner to reshape our world and create new ways of being (in this case for the ecological crisis), while right now the element most in need of change is the practice of design itself and a better definition of design and its epistemological stances, which attend sustainability and more-than-human needs.

The more-than-human actors can take an array of forms ranging from animals and plants to microbes and the weather. Excluding these actors (and their voices) from the design process ultimately leads to the assumption that they function as static, or as Latour and Weibel (2005) put it a: "matter of fact*"* This has led in recent times to a rapid decline in biodiversity both in and outside cities. Acknowledging these actors in the design process will help create new ideas about living together with the natural world, allowing for all to thrive (Smith, 2017).
My interest in this topic can be derived from the many meaningful experiences I have had as a child with the natural world. These experiences have led me to appreciate all kinds of manifestations of living beings and to this day I find myself marveling at the beautiful, unique, and weird ways nature can manifest itself. For me, this is reason enough to design for preservation but adding that the loss of such wonderful biodiversity also impacts humanity as a whole gives another layer of incentive to make sure design is conducted in, at least, a sustainable manner. With this thesis, I hope to build up knowledge on designing in such a fashion, which one day might help me convey such knowledge to other designers as well.
Within the theoretical background, I will focus on four issues relating to the climate crisis and how this is situated in the field of more-than-human design. While also drawing from the *posthumanism* movement in humanities studies. Posthumanism can be loosely divided into two sections: interaction concerning artificial entities & humans and interaction concerning the natural world & humans (Forlando, 2017). This project mainly draws from research on the interaction between the natural world and humans. The four issues found in this domain are:

1. Matters of concern instead of care
2. Disconnection with nature
3. Plant blindness
4. Human-centered design

From these four issues combined three design fields have been derived: *Design for Noticing, Design for Care,* and *Design for Cohabitation.* Additionally, a general lack in design practice regarding more-than-human design has been found, which has not necessarily informed a design field but is rather carried through the three listed design fields. Currently, the most accessible tools to designers build on human-centered design practice, while more-than-human design practices are left in obscurity. Therefore, this project has been largely informed by practices that find their origin outside of the earlier presented human-centered model. The design fields and earlier mentioned issues have together informed four design problems. The design problems are closely related to one other and together pose as the foundation of this thesis. The problems that have been derived from the four issues that situate themselves at the intersection between climate-conscious design and more-than-human design are:

1. Humans lack affective engagement with the climate crisis
2. Humans lack the awareness of being situated in nature and being interconnected with the natural world
3. Humans tend to be prone to plant blindness.
4. Designers currently lack a mainstream epistemology for more than human design

From these issues three research questions have been derived, with the main research question being:

> *"How can interactive technology be merged with the natural world to reinforce the notion that humans are situated in the biosphere"*

Additionally, two secondary research questions are formulated along with the first:

> *"How can interactive technology be used to promote care for non-animals?"*
> *"How can humans benefit from valuing more-than-human voices within their home environment?"*

I would like to elaborate on several of the notions above. By interactive technology, I mean artifacts capable of producing some form of computation, while maintaining an input-computing-output structure. Non-animals refer to all organisms that are not within the animal kingdom, meaning that with this notion I refer to plants, fungi, micro-organisms, yeasts, etc. However, this project is mainly concerning plants. With more-than-human voices, I refer to contextual influences that can originate from any actor within the local network of things. Meaning that both living and inanimate objects can be considered to have a voice. However, again, here I mainly focus on the voices of plants as actors in their network. Finally, the home environment refers to the environment that can, in contemporary views, be considered urban areas. This includes indoor spaces, gardens, parks, streets, etc. I would also like to mention that in Appendix A, a list of working definitions can be found that have been used as a reference guide by me during the project.

This thesis intends to contribute knowledge in two ways to the field of more-than-human interaction design. The first is going through a more-than-human design process and documenting this so that it may function as a reference point (and hopefully an inspiration) for future more-than-human designers. Secondly, I have developed several frameworks for this specific project to use in the evaluation of canonical examples as well as evaluating ideas. With this framework, I hope to contribute to working on developing a more-than-human design practice.

2. BACKGROUND THEORY

This chapter functions as a theoretical grounding of the claims made in the introduction. It will work through the different issues presented in the introduction and the subsequent design fields that have emerged from these issues. Finally, it will set the stage for the next chapter, by introducing a two-part framework used to assess the canonical examples relating to combining technology and plants.

Issues in More-Than-Human Climate Conscious Design

Coming to Care about our Concerns

To understand *matters of care* we first have to look at how Latour and Weibel (2005) describe *matters of concern.* They formulate a working definition where the notion is considered to be a dynamic interplay between things that are in constant negotiation. Within the context of the climate crisis, a comparison can be drawn where humanity is in negotiation with the natural world. According to Puig de la Bellacasa (2017, p.10) *"Thinking in the world involves acknowledging our involvements in perpetuating dominant values rather than retreating to the sheltered position of an enlightened outsider who knows better."* Even though Latour and Weibel acknowledge having a place in a network, they do not account for affectional engagement. Therefore, Ratto (2011) expands Latour and Weibel's notion by introducing the concept of care. He positions "caring for" in opposition to "caring about", where "caring for" facilitates the means for creating meaning, allowing in his case for connecting technology and society, However, this could also be applied in the relationship between society and the natural world. Similarly, Jönsson et al. (2019) advocate for making *matters of concern, matters of care.* They say that a matter of concern bears a connotation of something that can be discussed but has little to do with those discussing, elaborating: *"The notion of matters-of-concern suggests a distance between the concerned and the matter, and 'mere' intellectual engagement… …design and designers are not separate from matters of concern but deeply intertwined".*

Out of Touch with Nature

Another issue relating to the topic is the anthropocentric view of nature, and how this is viewed as separate from culture, society, or the city, leading to humans losing "touch" with nature. This can be broken down into three separate issues:

1. The notion that people can experience nature in a pure sense, that has not been influenced by any human disturbances
2. People cannot experience the natural world in domesticated areas.
3. People do not feel connected with nature

The first issue, the purity of nature, is a misconception because at this point even the remotest and most inaccessible parts of the world have been influenced by humans and their activities. Microplastics can be found on the very bottom of the ocean (Peng et al., 2018) and invasive species have been brought along by humans to new habitats. Environmental lawmaker Jedediah Purdy (2018) remarks: "*The natural and the artificial have merged at every scale. Climate change makes the global atmosphere, its chemistry, and weather systems, into Frankenstein's monster. […] If Nature were a place, we could not find it. If Nature were a state of mind, we could not attain it."* Purdy builds on the notion that during the Anthropocene the end of nature has come. It is important to note that the *end-of-nature* does not describe the end of the natural world, just the idea that nature and culture are deeply intertwined (Smith, 2017). This brings us to the second issue: people think they cannot experience nature in their domesticated surroundings. Humans tend to experience the separation of nature and culture as truth, this means that people dwelling in these highly cultural areas, such as cities and villages, experience a lack of nature. Leaving them to feel out of touch with nature (Crain et

al., 2014). Finally, people see nature as something external, outside of the human influence sphere, which means people will not see themselves as part of nature, but at most a visitor. This deepens the perceived division between humanity and the natural world and reinforces the idea that humans are external actors in the biosphere. This leads to people distancing their self from being part of the natural world. Schultz (2000) notes: *"The type of concerns an individual has for environmental problems are associated with the degree to which the individual includes nature within his or her cognitive representations of self.* (p.10)" Showing us that this division has negative consequences on the perceived importance of nature for the self. The perceived division ignores the many ways that the natural world has found ways to persist and thrive in these areas, creating new habitats that previously did not exist. Acknowledging the natural world as a part of the cityscape allows for entangling culture and nature even further, and giving a voice to these more-than-human city dwellers will also establish their place in the perceived context of human citizens. Building on the notion of *naturecultures* will help perceive both the more-than-human as part of human-scaped environments as well as perceiving humans as a part of the natural world, exposing the existing bonds that are shared between culture and nature.

The Art of (Not) Noticing Plants

Before diving into the third issue, I would like to introduce the concept of "the art of noticing", proposed by Tsing et al. (2017). In their book, Tsing et al. describe how Anthropocentric views, based on western ontology, have alienated humans from learning from the "open-ended gatherings" that make up our natural world. Gatherings where different species encounter, exchange, and be together. Tsing et al. advocate for turning our attention away from the "Anthropo-" and spend more time analyzing these assemblages to benefit all species involved and to learn from and gain insight into the intricate way of the workings of the natural world, through noticing the activities that unfold outside of Anthropocentric ideals (Liu et al., 2018; Tsing et al., 2017). This brings us to the third issue I would like to address is *plant blindness*. *Plant blindness*, as described by Wandersee and Schussler (1999), can be broken down into four separate notions:

1. Not being able to perceive plants in their surroundings.
2. Not being able to see the crucial roles plants play in the affairs of the biosphere and humanity.
3. Not being able to admire the uniqueness of plants.
4. Assessing plants as inferior to humans.

These conceptions lead to a series of unwanted results in human behavior, most notable for this research: people think plants function as a stage for animal life to develop; people do not see the importance plants have in their daily life (Balick & Cox, 1996); people lack awareness that plants are essential to phenological and ecological cycles (Wandersee & Schussler, 1999). Relating to the domain of this thesis project the main emphasis will be on establishing that plants do make up a significant part of the assemblage that makes our biosphere and how this is relevant for human affairs, as well as why plants should have a voice when designing for this assemblage.

According to Edwards et al. (2021), *Design for Noticing* can be established by incorporating a multidisciplinary approach, incorporating, and favoring a large array of creative approaches to create lasting experiences and meaning out of these experiences. Similarly, Rugg (1998) describes two critical factors that determine whether an experience will have lasting effects: How much attention we give it and how much meaning we attribute to the event.
This is further reinforced by Hecht et al.'s (2019) "interwoven experiences", which describes that direct and constant experiences with nature feed deeper interest in the natural world and

help to build an identity that associates itself with the natural world. Strengthening the association people experience with the natural world. Similar to what was mentioned earlier where this association of the natural world with the self, is crucial for developing a caring tendency towards it (Schultz, 2000).

Finally, I would like to point back to the mentality of "caring for" as opposed to being concerned about it. Krzywoszynska (2016) points out that care, attentiveness, and skill are connected. Meaning that increasing one's attention to a plant will also increase their ability to tend to it and their feeling of care towards plants.

More-than-Human-Centered Design

Finally, I would like to address that the three issues mentioned above, have also trickled down into design epistemology. Leading to designers who see the destruction of the natural world as a thing on a checklist to consider in human-centered design projects, motivated by mainly anthropocentric, progress-driven industry pursuits. Often as designers, we are expected not only to create products that facilitate being and culture but also there is the notion that designers should shape new ways of being. Therefore, I would like to highlight three areas of necessary change within design ontology:

1. Academia should promote cross-pollination between cultural and technical sciences (Crain et al., 2014; Ratto, 2016)
2. Academia should start viewing nature and culture as an assemblage of encounters, exchanges, and situations (Smith et al., 2017; Tsing et al., 2017; Brain, 2018b)
3. Design should shift its perspective from human-centered design to more-than-human-centered design by developing a more-than-human design epistemology (Forlando, 2016; Tsing et al., 2017).

One of the primary issues making it hard for designers to attend to socio-technical issues is the academic division between cultural and natural sciences. Ratto (2016) argues that in doing so the notion of culture being separated from nature is being kept alive indirectly, this is then also translated into the practice of the different disciplines. Similarly, but more specific to design, Forlando (2016) says: "The majority of designers are not trained to think critically about socio-technical problems and ethical challenges that are raised by emerging technologies." Additionally, Forlando (2016) mentions that there is little opportunity for designers to gain experience in tackling problems that address both socio-cultural and technical problems, constrained by corporate design briefs. This leaves little room for reflection on whether the existing epistemology is adequate to deal with socio-technical problems and little room is there for exploring these problems in a socio-technical setting. Theorist Françoise Vergès (2017), coming from a socio-cultural standpoint, elaborates that technology can only provide a partial solution if it is not accompanied by a shift in perception and values. Especially for the field of HCI with its deep roots in technological advancement would benefit from entertaining both views.

Bringing us to the second issue, that of the perception of natural science academia on ecology as a system. Tega Brain (2018b) advocates against looking at an ecosystem as an eco-system and says: "Components of a system are implied to be static discrete units, leaving out processes of contamination and transformation". Instead, they take up the notion of Anna Tsing's (2017) assemblages, also mentioned above. Tsing elaborates: "Patterns of unintentional coordination develop in assemblages. To notice such patterns means watching the interplay of temporal rhythms and scales in the divergent lifeways that gather." She continues by incorporating the socio-cultural: "Assemblages cannot hide from capital and the state; they are sites for watching how political economy works." Meaning that an assemblage, in contrary to a system, is an imperfect descriptor, but offers continuity and the possibility of mutation (Hayles, 2005). This allows for acknowledging different actors and influencers

within the system recognized across different disciplines, which then further ties into the necessity to cross-pollinate between the different sciences.
Finally, there is an issue with human-centered design, something that has become ever more prevalent within the field of interaction design, through participatory and co-design practices but also through a consumerist mentality that feeds the industry. As explained earlier most design projects build on a model where the human is central, even to the extent where if it does not meet a human need, it can hardly be interesting to companies to produce. Emphasizing the human means that other aspects of the process cannot be considered well enough (Wendt, 2017). Wendt explains: "If humans are at the "center," then things like environmental sustainability, social justice, care for ourselves, economic equality… most political aspects of design, cannot be adequately considered". Along with Wendt other design scholars advocate for decentering the human in design as well. Forlando (2016) writes: "I propose that purposefully decentering the human (often conceived of as a discrete individual subject) and embracing multiple and nuanced forms of hybridity offer a way of enabling designers to think and act more critically about their responsibility to design more ethical ways of living and working in cities given socio-technical complexity." Showing how decentering the human will allow for more critical thinking with regards to cohabitation. Smith et al. (2017) add: "a decentering of the human in design blurs the boundaries between people and things, emphasizing the interconnectedness that is inherent in human/nonhuman assemblages." Meaning that decentering the human contributes to the earlier mentioned *Matters of Care.*

Derived from the different issues that have emerged on the intersection between more-than-human design and climate-conscious design I have created a model to assess the canonical examples found for a design collection. Figure 1 shows the model derived from the background literature.

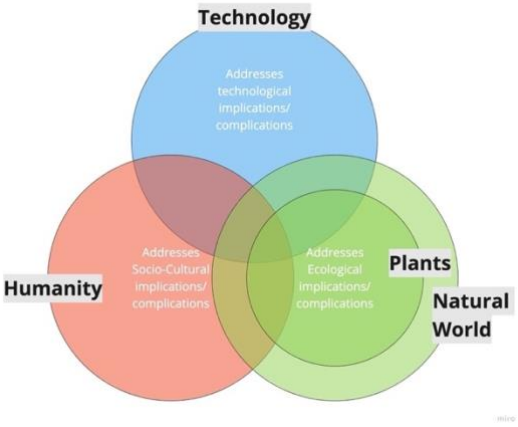

Figure 1: More-than-human issues model, to assess more-than-human projects

Design Fields

As mentioned in the introduction, the four issues described above have been translated into three design fields which together form a design landscape for more-than-human design with plants.

Figure 2: Image sequence showing attention and meaning making. The drawings are made for and first published in the book Growing by Darko Aleksovski, published by PrivatePrint, Skopje, 2016

Design for Noticing

Derived from the literature and heavily building on Edwards et al. (2021) work with the following definition for *Design for Noticing*: facilitating paying attention to the natural world and to see the natural world and culture as two entities that exist in the same space. This means that it addresses the two earlier mentioned notions presented by Rugg (1998):

1. Allow users to pay a greater degree of attention.
2. Allow users to attribute meaning or importance.

Building on this, Edwards et al. (2021) mention that a lack of meaningful engagement with the natural world and a lack of time spent with nature, are among the main issues when it comes to *Design for Noticing*.

An interesting example is the book *Growing* by Darko Aleksovski (2016). This book is filled with sketches from the garden of Aleksovski's parents (Figure 2). The sketches tell an intimate story about growth and a familiar place (to the author). In an interview I held with him about his book, Aleksovski mentions that making this book has attributed new meaning to the garden. An interesting quote from the book is: "You can see all the trees from here and you can see the plants from over there", to me this points out both a certain knowledge about the garden as well as a keen eye for the plants that make up the garden. Since this thesis mainly addresses plant blindness, additional notions can be added to facilitate the necessities for *Design for Noticing* as described above.

And like Krzywoszynska (2016) notes that promoting attentiveness also aids in developing feelings of care for more-than-human entities.

Design for Care

In light of this thesis, *Design for Care* is about the notion that people need to see nature as an extended part of themselves, not as opposition or something that is merely there. This is heavily built on Schultz's (2000) notion that the care people have for the environment is related to the degree they associate nature with their extended self. It shows a degree of affection, not to be confused with empathy. Two notions that have to be mentioned concerning care are instrumentalization and anthropomorphism.

Instrumentalization is an existing theme when designing with plants. However, this is generally concerned to be harmful because it undermines building a caring relationship with plants, by forcing plants into the role of artifacts rather than living beings. It also further

emphasizes the incorrect notion of humanity controlling nature. Leading to the misconception of plants being lesser beings.

Even though anthropomorphism has been proven to promote empathy towards the anthropomorphized, it tends to establish a relationship that is built on human values and norms. This means that the more-than-human entities that are being anthropomorphized lose the freedom of their being and are expected to act along humanized guidelines. This does not embrace the uniqueness of the more-than-human entity and ultimately only serves a human-centered approach.

Design for Cohabitation

Within the scope of this thesis, *Design for Cohabitation* reflects how human and more-than-human actors can also benefit from living together. This rather pragmatic approach to the relations formed between species, by itself does not necessarily account for noticing and care. Although most more-than-human projects situate themselves in this field of design, This Design field tends to be wrongfully interpreted as advocating for humans controlling nature. This in turn creates the illusion that humanity is successfully systemizing nature and it also validates that the systemization of the natural world is a valid approach. As mentioned before, systems cannot sufficiently address the complexity of a biological assemblage as shown by Brain (2018b) and Tsing et al. (2017). The true nature of this Design field lies in mutual benefit and can therefore be paired well with the other two design fields.

Together the design fields form a design space that can be used to evaluate ideas and concepts and inform designs within the scope of more-than-human design (Figure 3). Along with the more-than-human actors model, it forms the basis of the evaluation tool used to evaluate the design collection in the next chapter. However, before moving on to the design collection it is important to mention the relevant living material qualities that inform a large portion of the projects in this collection.

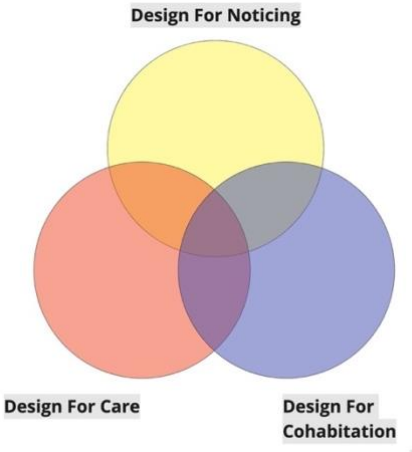

Figure 3: Design field diagram for assessing more-than-human designs

Living Material

The living material[1] research consisted of two separate parts: Autoethnographic material research, a literature study of plants as a living material. In this section I will not cover the autoethnographic material research, this can be found in chapter 5. I will elaborate on three main findings of the literature study: electrical potentials generated by higher plants, symbiosis resulting in bio photovoltaics, and sound as an influencer on plant growth.

Electric Plants

Higher plants have been studied in the field of biology for their capability of producing electrical potentials (Yan et al., 2009), however, this has yet to be thoroughly explored in HCI. As mentioned earlier, projects within interaction design and HCI utilizing this material quality do exist (*Plant Wave*, 2020; Sedbon, 2018b) but remain on the fringes of the discipline. Drawing from the field of biology, four different ways of measuring electrical potentials can be found, of which extracellular measurement is the most accessible (Yan et al., 2009). Zhao et al. (2013) and Yan et al. (2009) describe that these potentials can be generated by a series of different stimuli, most notable: light, temperature change, touch and tear, and leaf movement.

Symbiotic Spark

Plants have also been known to maintain symbiotic relationships with microbes in the soil. This relationship encompasses an exchange of nutrients which allows the microbes to produce free electrons and radical hydrogen. The hydrogen dissipates through the soil, while the electrons can be harvested (McCormick, 2015). This creates a potential difference between the top layer of the soil and the bottom layer. This effect is strengthened by keeping the plants and microbes in water. Some products and concepts already exist using this technology as I will describe in the next chapters.

Plants love to Listen

Khait et al. (2019) describe how airborne sounds can affect different plants and how these plants may respond differently to similar sounds. These different responses range from sweetening fruits to growing in certain directions. Chowdhury and Gupta (2015) also show that certain types of music may stimulate plant growth. Some people also theorize that speech may be beneficial to plants as well (Dodd, 2021)

[1] A slight disclaimer is also necessary here, even though I speak of plants as living materials I want to emphasize that I do not want to reduce them to static and/or inanimate materials. I would like for you to see them as material, similar to how humans or behavioral traits of humans can be considered material as well.

3. DESIGN COLLECTION

In this chapter I will take you along on my research on the current state of the field of more-than-human design, more specifically, combining interactive technology and living materials. To do so, I have assembled a design collection with existing projects, most of which are situated within the field of HCI. I have broken it down into four insights I deem relevant to share:

1. Genetics and Bioengineering is one of the leading interests
2. Conceptual Design tends to be the norm
3. Audiences and Exhibitions
4. Technology as the voice of Nature

I conclude the chapter with an evaluation of the domain, by providing some insights relating to cross-examining the different projects. Throughout this thesis, I will mention several projects, but the collection is not limited to those projects, an extended list of all the projects in this collection can be found in Appendix B.

The Small Things Matter

The first insight I would like to address is that unsurprisingly bioengineering and genetic manipulation form are a major influence on the field of designing with living materials. Projects such as *Data Garden* by Grow Your Own Cloud (2020) seek to intertwine the natural data holding capabilities of living materials, in this case, the DNA of plants, combining the field of Genetics and Software Engineering, to create a new way of storing information to combat the vast amounts of energy consumed by contemporary data centers (Figure 5). David Benqué on the other hand approaches Synthetic Biology from a less pragmatic perspective. His *Acoustic Botany* (2010a) and *Silvery Acres* (2010b) are designed to have an entertaining value and seek to explore the cultural implications for genetically modified plants. The modified plants from his project *Acoustic Botany* form a sound garden, to further develop aesthetic interactions people can have with the natural world (Figure 4). He mentions: "…we have been shaping nature for thousands of years, not only to suit our needs but our most irrational desires." Exploring the sound garden in his project *Silvery Acres* he opens up about what these plants might bring in the future. These two projects reflect the earlier discussed division between natural and cultural sciences and together form a domain within which socio-technical challenges may be explored.

Figure 5: the Data Garden (Data Garden, 2020)

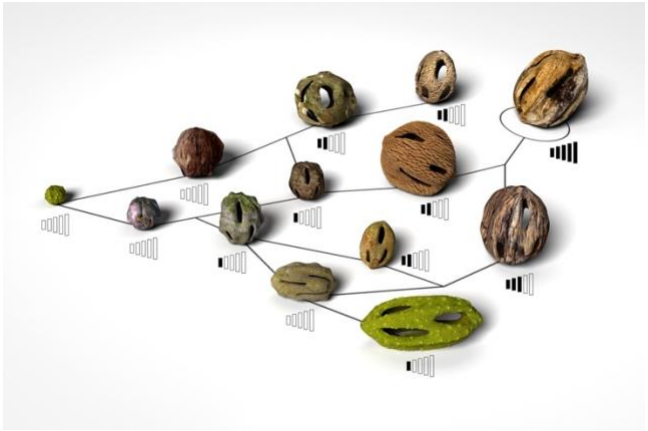

Figure 4: Conceptual genetically modified fruiting plant parts (Benqué, 2010a)

Conceptual and Critical

Most of the projects that I have encountered carry heavy conceptual undertones, most notably from the fields of Critical and Speculative Design. Tega Brain has developed two projects which start to explore the socio-technical challenges associated with designing for humans and nonhumans through the use of technology. The first, *Coin-Operated Wetland* (Figure 7), is a project that sets out to reconnect people with the habitats, in this case, a wetland, that provide them with necessary ecological benefits. It aims to pose critical questions about how humanity cares for its ecology and provides an almost satirical solution to the issues that arise from the disconnect between people and nature (Brain, 2011). The second, *Deep Swamp* (Figure 6), is a complicated dialogue between three AI's that care for a piece of wetland situated in an exhibition area. One aims for the best care possible, the second for aesthetic expression, and a third "just wants attention" (Brain, 2018a). This project explores the dialogue the natural world can have with technology, whilst maintaining a human-centered design in the form of designing for aesthetical experience. It raises questions about systemizing the natural world for the sake of human appreciation and understanding. Similarly, Michael Sedbon situates his projects in borderline conceptual projects. I say borderline because within the conceptualizing of his projects Sedbon also tends to provide proof of concept. *CMD* is one of those projects, here Sedbon has put two cyanobacteria colonies in competition with each other over a light source, using artificial intelligence to manage a market (Figure 9). With this project, Sedbon aims to explore socio-technical issues

Figure 7: Coin-Operated Wetland (Brain, 2011)

Figure 6: Deep Swamp, three artificial intelligences control a wetland (Brain, 2018a)

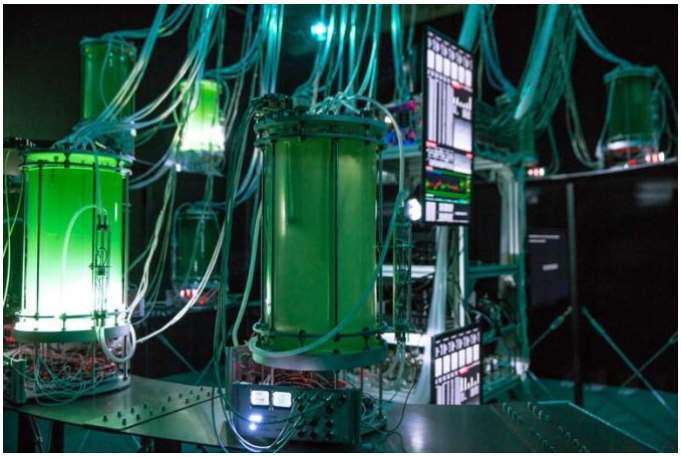

Figure 9: CMD; Cyanobacteria competing for light (Sedbon, 2020)

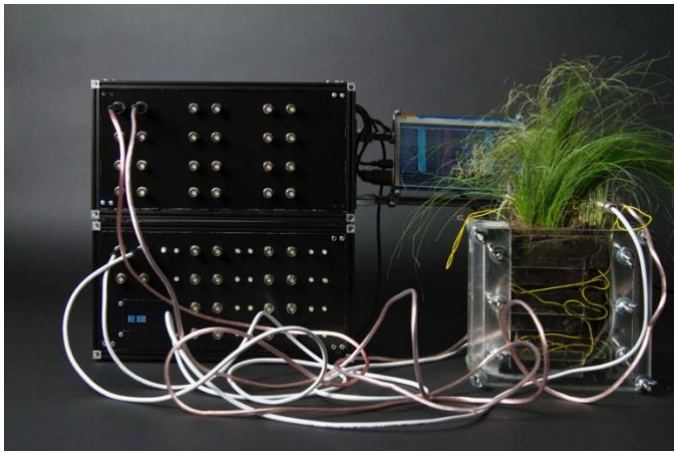

Figure 8: ALT-C, using bio photovoltaics to mine cryptocurrency (Sedbon, 2018a)

surrounding biological computing (Sedbon, 2020). Similarly, *ALT-C* explores the socio-technical implications of an AI dependent on the natural world for its energy consumption, forcing its "voice" in the capitalist market through cryptocurrency mining and stock trading (Sedbon, 2018a) (Figure 8). Although these projects draw from more-than-human design research, they tend to instrumentalize the "nature" that is involved in the projects and capitalize on their material properties. This forms a dichotomy within the earlier established design fields (noticing, care, and cohabitation) by mainly focusing on the cohabitation aspect, but not building healthy relationships between humans and the natural world. Ultimately, humans, as individuals, play only a small role (if any) in these conceptual projects. This brings us to the next insight.

Come and See

Relating to the previous insight, it is notable to say that due to the projects' nature within conceptual design, most of the previously described projects are designed for exhibition areas or function as a probe to explore possible futures. This means that even though some of these projects apply interesting principles from HCI, they are often not meant to be interacted with, but rather to be experienced by an audience. As Dunne and Raby (2013) note, this has strong implications for audiences' worldviews. However, to move forward, there is a necessity for embodied experiences to further deepen the understanding and implications of such projects. First steps are being made in this direction, for instance, *Plant Wave* by Data Garden (2020) (Figure 10). This device is commercially available and utilizes the plants' electrical potentials to create unique music, exploring, similar to Benqué, aesthetic qualities of nature in a cultural setting, only now aided by technology. Reflecting on the earlier distinguished design fields: noticing, care, and cohabitation, this project allows users to form new and meaningful experiences which were previously unavailable. Arguably facilitating the development of care and noticing. Another example that starts to bridge conceptual projects into the domain of cultural space is Plant-e's market available products, using bio photovoltaics (a term I will come back to later in the thesis), to facilitate a continuous source of electricity based on plants (*Hoe werkt het?*, 2021). Although not bridging the socio-technical gap, this product provides a tangible and usable solution and helps not only consumers but also citizens to envision alternate futures.

Figure 10: Plant Wave hooked to a plant (Plant Wave, 2020)

Figure 11: Wood-Wide-Web 1.0, Aestheticizing plant communication (Sedbon, 2018b)

Technological Voices

The final insight I would like to share is the use of technology to advocate for plants. For instance, in the earlier mentioned *Deep Swamp, Alt-C,* and *CMD,* technological entities (AI's) are advocating for plant desires. This happens to the extent that the human actor is not actually in dialogue with the plants, but rather in dialogue with a digital interpreter of the plants. A project that leaves the language of plants open to interpretation is Michael Sedbon's *Wood-Wide-Web 1.0* (Figure 11). This project aims to aestheticize plant communication channels, without casting them into culturally conforming ways of communication. The project leaves open how the different visual and auditive stimuli may be interpreted. With this, the project shows how people might get to know their plants by eventually recognizing unique patterns after certain interactions, or how the plants might be able to communicate to people that air quality is low. In a sense, this project shows implications for a relationship between plants and humans that might become codependent and symbiotic rather than instrumentalized.

Reflecting on the Design Collection

The analysis has left me with several conclusions. Although the conceptual approach to this domain has fruitful results, it is necessary to move out of the installation and exhibition setting and move into the daily lives of people. Furthermore, I see a trend where most projects capitalize on one of the material aspects of plants, whether this is their electrical potentials, the capability of producing electricity, or their genetics. Arguably, this signifies that there is a lot to gain from combining these material aspects and mapping out the different material capabilities similar to how inanimate materials have large databases of material properties. This would be beneficial for all disciplines looking to draw from the fields of Biology, Ecology, and Biological Engineering. Perhaps most notably it will make contemporary tools and knowledge accessible to designers (of all sorts) to start exploring the socio-technical implications that follow the use of these materials. Finally, I see a lack of canonical examples situating themselves on the intersection of technology, nature, and human. Projects such as *Plant Wave* are a good example of how we might start doing so. In Chapter 5 I will elaborate further on how evaluating the design collecting has informed the project.

4. METHODS

In this chapter, I will address several methods I have used throughout this thesis project. I would like to emphasize that the choice of materials has largely been influenced by a desire to promote methods that find their origin outside of industry-driven design. Therefore, most methods used find themselves affiliated with existing more-than-human, conceptual methods, material-driven, and participatory design methods. Before addressing the methods, I would like to elaborate on the design process model that was followed, to further strengthen the reasoning behind the methods.

Design Process Model

The design process for this project has been loosely based on the *double diamond model* (Figure 12). The double diamond model consists of four phases which can take many names, in this thesis project they are referred to as *Research, Synthesis, Conceptualization, and Finetuning.* Cat Drew (2019) informs that originally the model has been developed as a tool to visualize the design process and more notably the relevance of spending time and money on all parts of the process concerning the problem the design had to solve. In turn, the model has a solution-oriented focus, originating from industry desire. Based on the background information presented in the earlier chapters I have decided to alter the model to suit this project. To do so, I have drawn from both Critical Making as proposed by Matt Ratto (2011) and Speculative Design as described by James Auger (2013).

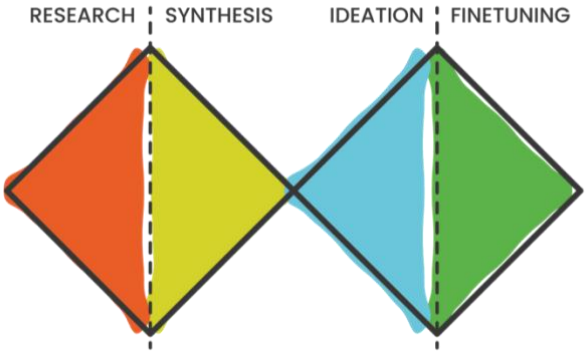

Figure 12: Double Diamond Model

Critical Making has informed this project mainly in the manner of conduct. Ratto (2016) describes the Critical Making process as follows: "Rather than focusing on a method or a specific practice, critical making involves an evolving series of commitments that include a sense of complicity and responsibility for the state of the sociotechnical world and a desire to transform it." Which shows us that it emphasizes an "ongoing-ness", a notion that it is never finished, similarly *Design for Care* emphasizes an ongoing commitment to actors within the design domain. Furthermore, it shows a large emphasis on contributing to design practice and self-critiquing. Ratto (2011) mentions: "Critical making emphasizes the shared acts of making rather than the evocative object." Further showing that Critical Making contributes to developing the field rather than serving the industry. Finally, it shows a large emphasis on materiality. According to Tung (2012) the material, context, and similar products should first be understood before adequately being able to address the design process. Together Ratto and Tung have informed this project to be more material-oriented.

According to James Auger, Speculative *Design* serves two main purposes: critiquing current practice and envisioning alternative futures (2013). Furthermore, Anthony Dunne and Fiona Raby add that Speculative Design should provide the audience with an alternative to the

current market-driven context of design (2013, p.14). Speculative Design finds its origin outside of industry-driven design practice, therefore providing a rich pool of research and examples that either decenter the human or envision a future that creates a setting outside of the contemporary consumer-driven market. This thesis has been mainly informed by *Speculative Design* by its emphasis on research and understanding the context as well as utilizing tensions to make informed decisions during the ideation phase (Mitrović et al., 2021).

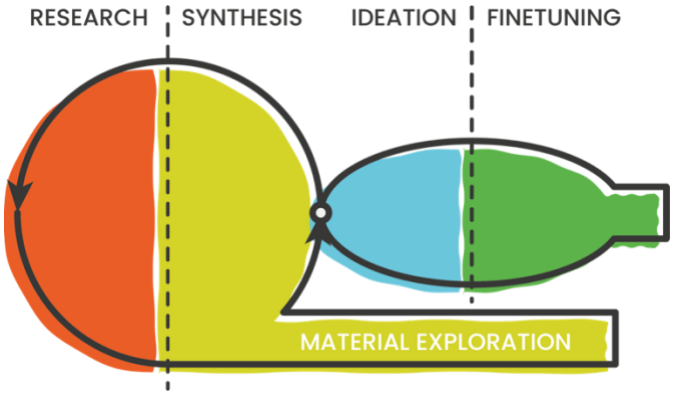

Figure 13: Changed and adopted the Double Diamond model

The result is a design process model with a large emphasis on the first half of the double diamond model along with a parallel track of material exploration throughout the project. (Figure 13).

Research

Literature Review
This method is about collecting and synthesizing information on a certain topic. It is most suitable for summarizing a large portion of knowledge (Hanington & Martin, 2019). To become more familiar with more-than-human, posthuman, and speculative design I have opted for reading up on notable research and theories.

Material Exploration
Informed by Ratto's (2011) *Critical Making* and inspired by the project described by Jönsson et al. (2019) on care throughout the process of the workshop, this method can be divided into two almost contradictory parts. On one hand, I wanted to understand plants as a material, by critically making different setups that might inform the project. While on the other hand, I wanted to adopt a caring mentality throughout the project, similar to how Jönsson et al. describe that they were careful to make caring a central piece of being in their workshop.

Personal Ethnography
Crawford (1996) describes personal ethnography (autoethnography) as utilizing the ethnographer's repositioned self-consciousness as a site for gaining insight into personal awareness and interest while revealing specific insights regarding the settings with firsthand impressions. Cunningham and Jones (2005) add that autoethnography, can form a good alternative to projects tight in time.

Design Collection
The Design collection in the context of this project has several functions. It shows the state of the field as well as inspires the ideation process. Furthermore, it aids the designer in

understanding what makes up a good project regarding the topic they are tackling. Parsons (2019) further notes that evaluating projects done before can inform the design process in more quickly assessing correct fits for the project. The collected knowledge might save time on testing.

Synthesis

Mind Mapping
This method was chosen to do so because it provides an overview and allows for different relations to be seen, which might otherwise stay obscured. According to Zijlstra and Daalhuizen (2020) mind mapping also helps with decluttering the brain, bringing "structure and clarity".

Affinity Diagramming
This method visually clusters insights and observations into clusters and relations. The clustering is done based on the collected insights, rather than using predefined categories, to see unexpected relations (Hanington & Martin, 2019).

Design Principles
To form a basis for the ideation process, a list of design principles regarding the different design fields established in chapter two was made. These principles together with other synthesis results formed the theoretical framework upon which the ideas during the ideation phase could be based.

Problem Definition
Although this project is not necessarily aiming to work in a problem-solving manner, it functions well as a means to narrow down the focus in light of time constraints regarding the project. According to Zijlstra and Daalhuizen (2020) a problem definition functions as a good starting point for the ideation phase to know what to ideate on. In the case of this thesis, the theoretical framework covers a lot of different areas to explore, hence making the problem definition method a good starting point to narrowing down the ideation scope.

Tensions
In addition to the design principles and problem, statement tensions have been established based on the projects from the design collection. I have chosen to work with tensions similar to how tensions are used in speculative design (Mitrović et al., 2021). Here they function as means to measure ideas and concepts on different axis and to theorize about their possible impact on society if exhibited or sold.

Harris Profile
This method is suitable for quick decision-making based on design criteria during the development of concepts (Harris, 1982). According to Zijlstra and Daalhuizen (2020), it is typically suitable to evaluate the ideas after the ideation process.

Ideation & Concepting

Design Drawing to Develop
According to Zijlstra and Daalhuizen (2020), it further aids visual exploration as well as reflecting and developing ideas further. During the ideation phase, these projects can be judged according to the theoretical framework established after the synthesis phase, which

then has the potential to yield several insights that can be fed into the theoretically backed ideation process. Furthermore, it helps to get it off the mind and focus your energy on other parts of the process once an idea has been documented, similar to mind mapping. See Appendix E for the full list of preliminary ideas and comments.

Participatory Speculative Design
In this method, participatory design and speculative design come together to discuss, create, and analyze. The workshop ends by contrasting the outcomes. The method aims to involve people in the design process to stimulate care and consideration for the issue at hand (Korsmeyer & Light, 2019)

Brainwriting
this method is based on the assumption that quantity leads to quality (Zijlstra & Daalhuizen, 2020). Usually, this is done in groups to kickstart the ideation process, by writing down ideas to solve a well-defined problem. During the method, judgment is postponed, and it is encouraged to explore ideas that might lead to a dead end.

Material Driven Design
This method aims to understand the material before designing after which problems and opportunities will be easier to list (Tsung, 2012). The method consists of three distinct phases: Understanding the current situation, envisioning new material experiences, and manifesting patterns. Furthermore, this method is appropriate for this project due to its emphasis on an experience-oriented perspective (Karana et al., 2015). Since earlier mentioned literature pointed out that a benefactor to reducing plant blindness and increasing interconnectedness with nature is creating meaningful experiences, this method is suitable to inform the ideation and concepting process.

Developing

Prototype
Houde and Hill (1997) describe a prototype (in the context of interactive objects) as something that represents the design idea and is aimed at answering design questions regarding the idea's role in human life, its look and feel, and/or technological implementation (Figure 14).

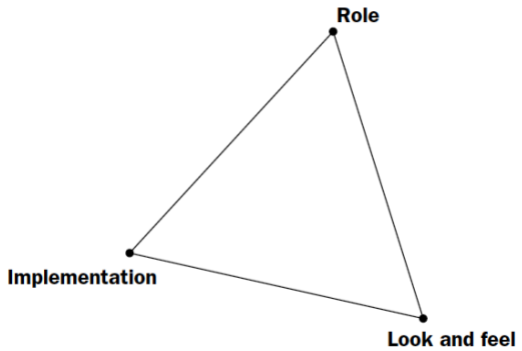

Figure 14: Prototype model developed by Houde and Hill (1997)

Wizard of Oz Prototyping

This form of prototyping utilizes a hidden person to act as a behavioral component for the prototype. According to Zijlstra and Daalhuizen (2020), this method works well, when trying to work out different options because it takes little time to set it up and does not have to involve complicated technology.

5. DESIGN PROCESS

Research & Synthesis

During the research phase, there were two main goals. Firstly, gaining knowledge of projects and theories within the more-than-human design field. Which also instigated the first attempt at creating a more-than-human design evaluation tool. Secondly, gaining knowledge on working with plants as a living material. This led to a material exploration. I will go into both of these trajectories separately since they both provided me with different challenges, I do however want to point out that these activities were conducted in parallel with each other.

Theory

As mentioned in the Background Theory, three Design fields became central to this project. The three fields all contribute to enhancing interconnectedness with nature in their own way. To address the main research question:

> *"How can interactive technology be merged with the natural world to reinforce the notion that humans are situated in the biosphere"*

Design principles were derived from relevant works within the respective fields, where *Design for Cohabitation* draws from Brain (2018b), Crain et al. (2014), Forlando (2017) and Smith et al. (2017), *and Design for Care* draws from Schultz (2000), Puig de la Bellacasa (2017), Krzywoszynska (2016), and Jönsson et al. (2019), and *Design for Noticing* from Wandersee and Schussler (1999), Edwards et al. (2021) and Tsing et al. (2017) (Figure 15).

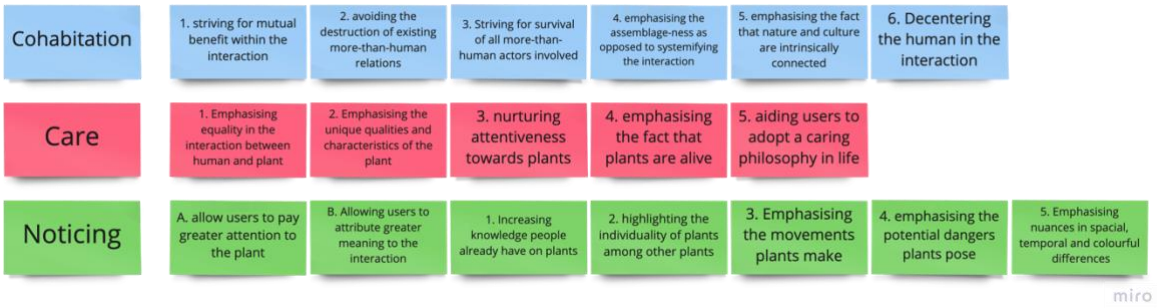

Figure 15: Design principles of each design field

In addition to the design fields, three more-than-human actors were: *Humanity*, *Technology*, and the *Natural World*. Although these can be broken up into more categories, and arguably humanity makes up a part of the natural world, they have been separated for maintaining a distinction between human desires and the desires of the other actors. Within the model, humanity can be considered to stand for socio-cultural desires, technology for technological desires, and the natural world for ecological desires. This model was used to aid in thinking about the implications of the projects in the design collection.

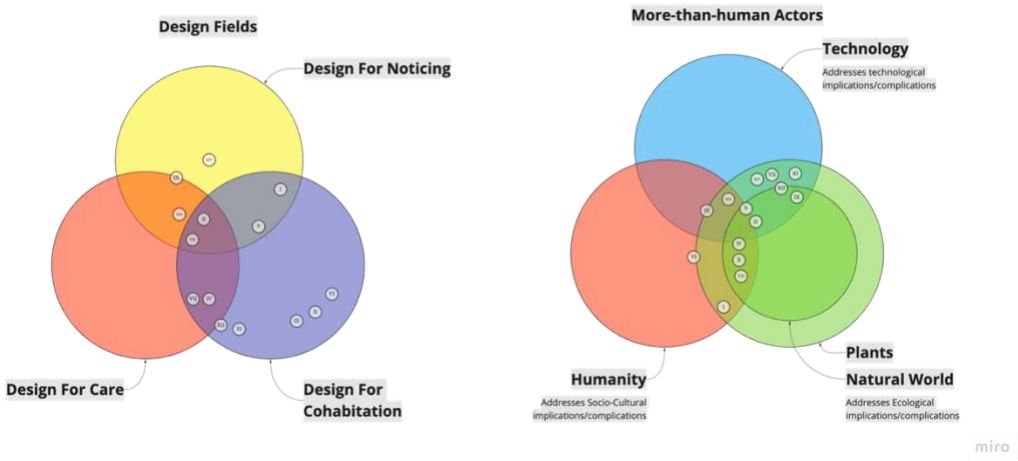

Figure 16: A Filled in excerpt from the design collection evaluation (see Appendix B for the complete version)

Design Collection

Throughout the literature research, existing projects were collected relating to combining technology and plants. This was done to compare and evaluate them. For each entry I wrote a short description, its relevance, a short critique based on the literature, and the main takeaways. Based on the literature, a small evaluation sheet was made to evaluate how the projects hold up to each other. The evaluation sheet contained the three design fields, the more-than-human considerations, and a conceptual scale. Placing all the projects in this diagram, informed me of the current state of the field and highlighted which projects seem to stand out (Figure 16, or See Appendix B for the complete evaluation). Furthermore, the features of the different projects were collected in an affinity diagram, which, after clustering, yielded the tensions seen in Figure 17.

I realized that placing projects in the VEM diagrams, although useful to put things into perspective, gave an abstracted and somewhat arbitrary view. Therefore, I set out to be able to quantify my choices for the next time I was to evaluate work regarding the topic. To develop the evaluation sheet, I looked at other evaluation methods. A new model was developed, based on the *Harris Profile*, a method that aims to make choices in concept

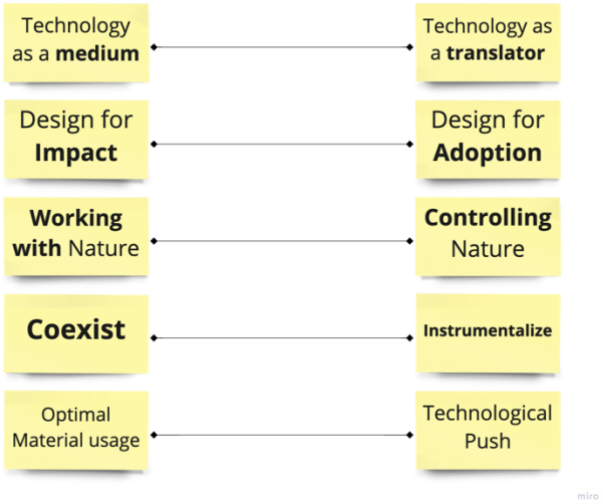

Figure 17: Tension derived from design collection

	-- Doesn't address this at all	- Addresses this issue inadequately	+ Touches upon this issue	++ One of its best qualities is this issue
NOTICING				
How well does this project highlight the uniqueness of the plant?				
How well does this project highlight temporal and spacial differences produced by the plant?				
How well does this project contribute to gaining knowledge of this plant?				
CARE				
How well does this project emphasize equality in the relation between plant and human?				
How well does this project emphasize the aliveness of the plant?				
How well does this project facilitate attentiveness towards this plant?				
COHABITATION				
How well does this project provide mutual benefit between the species involved?				
How well does this project facilitate coexistence between the species involved?				
How well does this project decenter the human in the interaction?				

Figure 18: Updated more-than-human evaluation tool

evaluation explicit and simple (Zijlstra & Daalhuizen, 2020). In this new model the design principles functioned as design criteria. The list of criteria was shortened to make the model simpler and quicker to apply. The result was a series of three *How* questions per design field. A new evaluation tool was created (Figure 18). To test this evaluation method, it was later used in the speculative material probing workshop to see how well it holds up.

Living Material Exploration

Alongside the Literature study regarding plants as a living material, a material exploration was done with regard to combining interactive technology and plants. An Arduino Nano and an Arduino Uno were used as an interactive technology and several different higher plants (e.g. a willow tree branch, a fern, etc.) as a living material. Alongside collecting and maintaining the different higher plants, materials for making bio-photovoltaic cells and a setup to read out electrical potentials were researched and collected. Researching this proved rather difficult, therefore I contacted an Arduino expert to aid me in selecting the right electrical components. Unfortunately, in order to determine certain components in the schematic of reading out the electrical potentials of plants, an oscilloscope was necessary, which I was not able to obtain. Trying to work around this I managed to simulate the effect

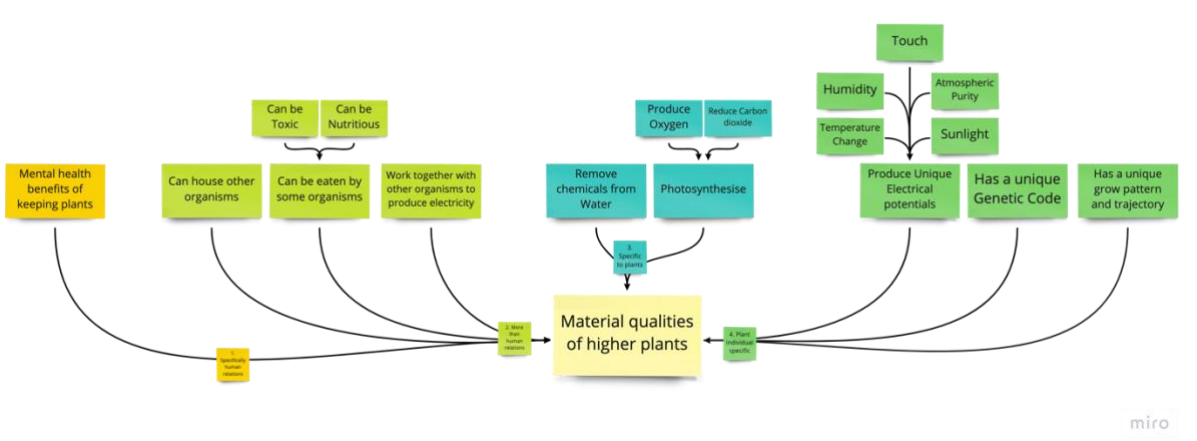

Figure 19: Map of higher plant material qualities

somewhat by placing a capacitive sensor on the plant to register if the plant is touched or not. Based on the literature research and my own experience, the unique material qualities of higher plants were mapped out for later use in the ideation process (Figure 19).

Defining the Problem

In order to advance the project towards the ideation phase a problem definition was formulated. I would like to remind you that the main research question posed in this thesis project is:

> *"How can interactive technology be merged with the natural world to reinforce the notion that humans are situated in the biosphere"*

Informed by this question and the earlier established theoretical framework a main problem definition was formulated:

> *"People do not feel intrinsically connected with nature and therefore do not care as much about nature"*

This definition informed an iterative process on formulating a suitable *How Might We* to further narrow down the ideation scope. Important aspects of the *How Might We* are a focus on plants, rather than the natural world and a focus on the users of the design manifestation. I would like to point out that the introduction of users here is not to undermine the more-than-human design process, but rather to give humans a place in being part of the solution alongside the other actors. The *How Might We* that was eventually settled on is presented below:

> "*How might we merge Arduino and higher plants to reinforce the notion that the user makes up a part of the local assemblage of more-than-human actors"*

Note here that in contrast to the research question interactive technology has been replaced with Arduino since this is the main interactive technology that I have been exploring in the material research.

Due to the literature review and material exploration having been narrowed down to mainly address bio photovoltaics and electrical potentials. I opted for using these as bases for the ideation process, alongside the capability of plants to grow in unique ways. To further inform

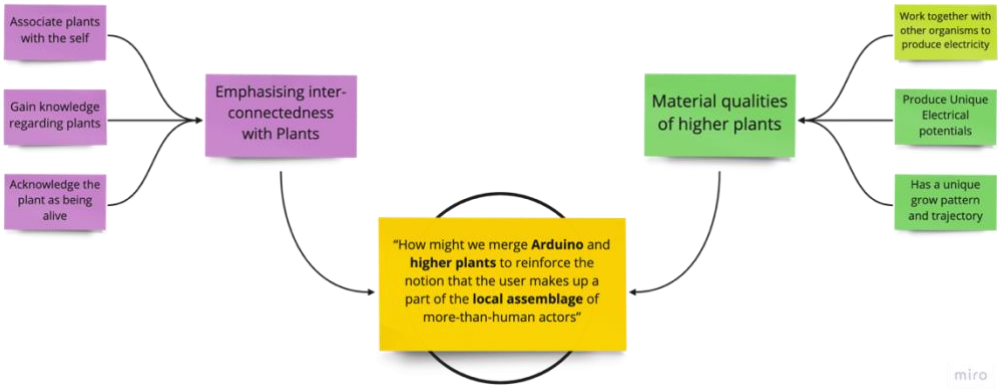

Figure 20: Ideation base

the ideation process I distinguished three influencers on interconnection with plants based on the background theory:

- Mentally, the degree of association of the self with plants
- Intellectually, the amount of knowledge people possess about the relationship between plants and humans
- Perceptually, the degree to which people acknowledge plants as being alive.

Arguably, by improving one of these influencers the general notion of interconnectedness with plants would increase among users. Together with the material qualities a narrowed down base for ideation was formed (Figure 20).

Conceptualization & Finetuning

Throughout the conceptualization and finetuning phases, I worked on two outcomes in parallel, a more-than-human design evaluation tool and a concept in line with the background theory

Speculative Material Probing: Exploring More-Than-Human Design Tools
In order to test and further developed the more-than-human design evaluation tool (Figure 18), I hosted a workshop. During this workshop participants were divided into groups. Their assignment was to ideate a more-than-human design based on one of the available plants. At the end of the workshop, the groups assessed each other's ideas based on the evaluation tool.

During the workshop, I presented the participants with an array of generative materials they could use to inform their idea (Figure 21). The materials provided were (Figure 22):

- Speculative Future Narrative
- List of living material characteristics (in the form of a presentation slide)
- Design field cards with *How might we's* based on the assessment diagram
- A tabloid template with prompting sentences
- A physical plant

Figure 21: Participants Ideating

Figure 22: Materials used in the Speculative Material Probing Workshop

Several insights were collected regarding the evaluation tool. The most important notions were, that participants generally disliked hierarchical evaluation methods to assess other people's work. Furthermore, not all questions were clear and some needed additional explanation from me during the workshop. A minor insight was that the evaluation of one project took longer than expected (15 minutes), which could be attributed to unfamiliarity with both the questions and the design field. Nonetheless, I would not place it in the same category as the *Harris Profile*, which is supposed to be a quick method.

Together with the participants a crude alternative was drawn. After which I researched several nonhierarchical evaluation methods and got inspired by the Eco-design Strategy Wheel. The strategy wheel provides an interesting way of visualizing competences of a certain idea or concept, by looking at surface covered rather than points scored. Appropriating the model to the more-than-human design evaluation tool, yielded a more appealing and less daunting tool: the Amoebae Wheel (Figure 23), which I would later on use in evaluating my own ideas.

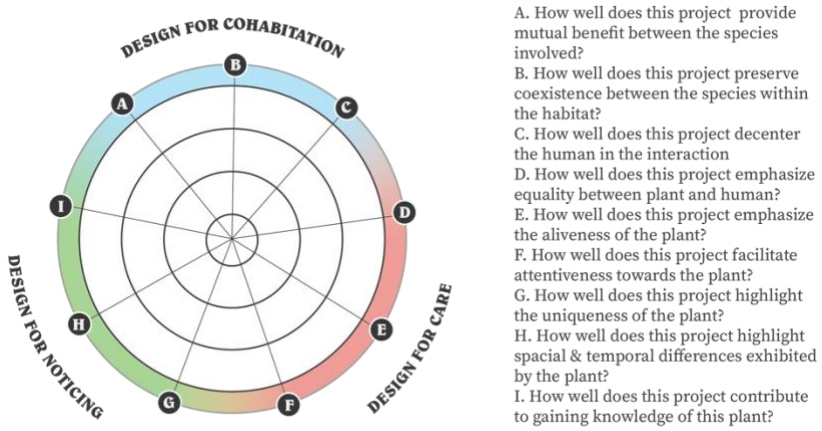

Figure 23: Amoebae Wheel, a more-than-human evaluation method

Ideation

The ideation process consisted of two parts, uninformed and theoretically grounded ideation. The uninformed ideation happened throughout the research and synthesis phase, where ideas

would pop up in my mind and I would crudely sketch its main components and annotate some functionality or purpose (Figure 25). Since most of these ideas were not based on the research, I compiled them and wrote pros and cons after which I placed them on the Design field VEM diagram (Appendix E). Later these projects would inform solutions and fixes for issues regarding the chosen concepts.

The theoretically grounded ideation started after completing the ideation base (Figure 20) and the speculative material probing workshop. During this ideation, I used design drawing to develop and brainwriting to come up with ideas. Based on the material-driven design method I opted for using at least one material quality and one of the notions to emphasize interconnectedness for each idea I came up with. This ideation process yielded eight ideas that were deemed within the scope of the project.

After ideating the initial ideas were narrowed down by placing them on the tension framework derived from the design collection (Figure 24). Within the framework, the tensions to the right were found to be less informative with regard to advancing the more-than-human design practice.

The ideas that scored reasonably on the tension framework were then evaluated with the Amoebae Wheel (Figure 26). This served two distinct reasons, evaluating the ideas in accordance with the earlier established design fields and evaluating the Amoebae wheel itself in order to see if it can be improved upon as a knowledge contribution to the more-than-human toolbox.
Using the evaluation tool allowed me to gain insight into how the ideas could be developed into concepts, by developing the shortcomings of each idea with respect to the different design fields. Finally, by applying the tool I realized that the Amoebae wheel is not (yet) suitable to be generalized for all more-than-human projects, but rather should be seen as a "designing for plants" specific tool.

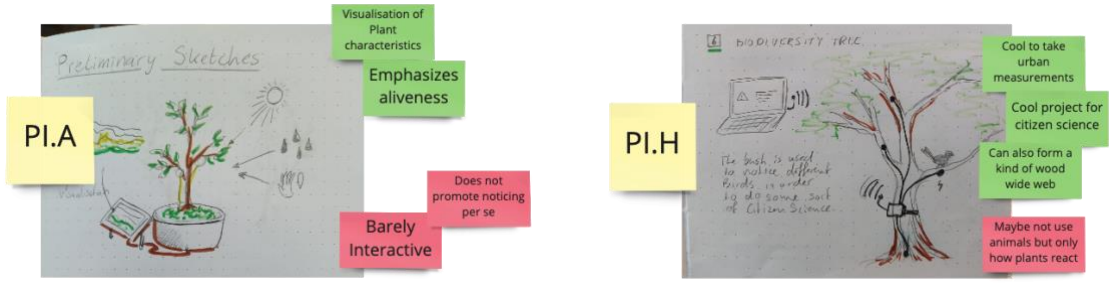

Figure 24: Examples of preliminary ideas

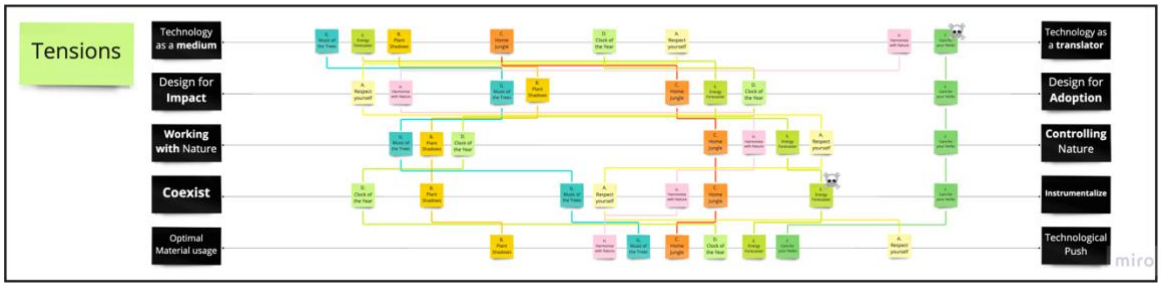

Figure 25: Narrowing down ideas based on the tensions from the design collection

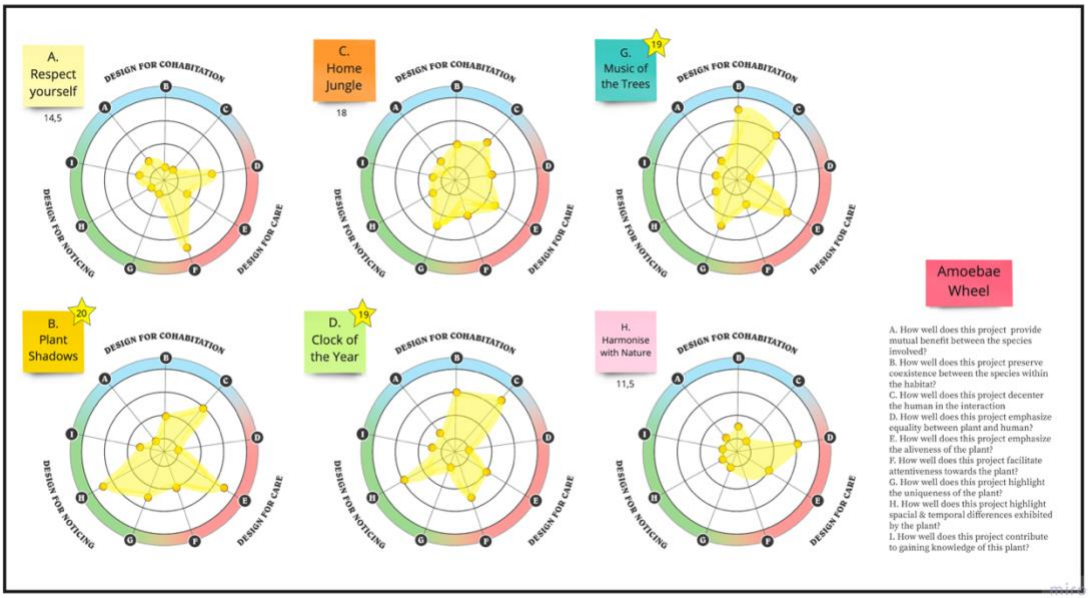

Figure 26: Narrowing down ideas based on the More-than-human evaluation model

Concepting

The three ideas chosen based on the evaluation struggled in particular with three notions from the Amoebae wheel. As a result, I listed potential solutions and fixes to address these issues in order to improve the evaluation "score" of the ideas and to develop them further into concepts. The solutions and fixes were drawn from discarded ideas that scored well on these notions and the speculative material probing workshop (Figure 27).

Iterating the concepts over the different solutions and fixes allowed for new crude ideas to emerge. These iterations were then assessed with a *Harris Profile*, addressing five major influencers on the project (Figure 29)

1. Interactivity, due to the project's nature within HCI and Interaction Design
2. Prototype-ability & Testability, due to the time constraints certain things are hard to prototype (e.g., growing plants over longer stretches of time)
3. Care is manifested in the "meaningful experience", as this has been linked to increasing the mental notion of interconnectedness with nature

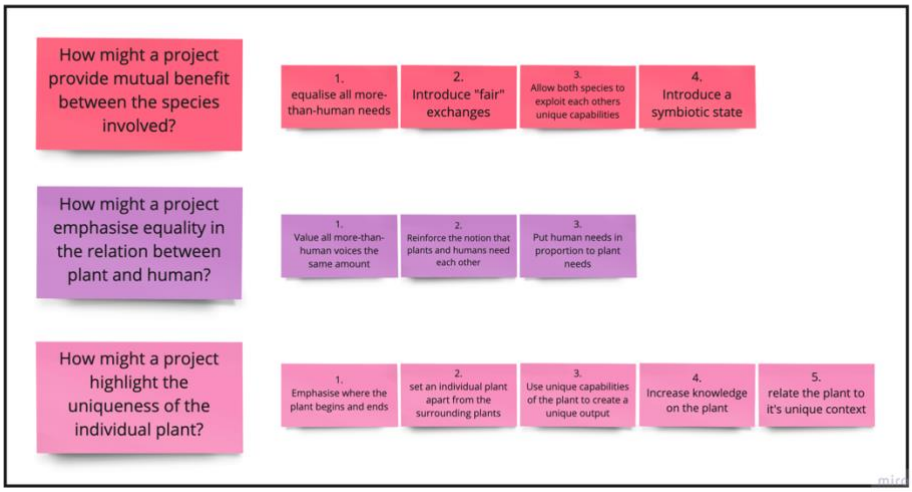

Figure 27: Input for iteration on three specific points of interest

4. Noticing, which is manifested in “attentiveness”, as attentiveness has been proven beneficial for perceiving interconnectedness with nature
5. Cohabitation, which is manifested in “equal exchange”, as this has been linked to increasing the intellectual notion of interconnectedness.

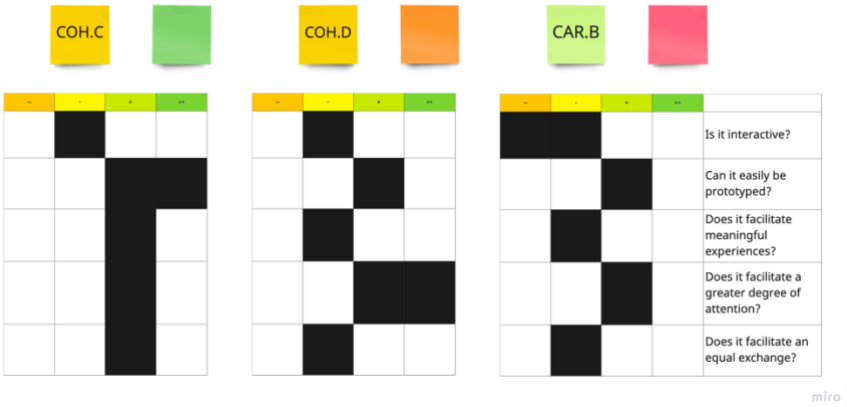

Figure 29: Examples from the Harris Profile evaluation of iterated ideas

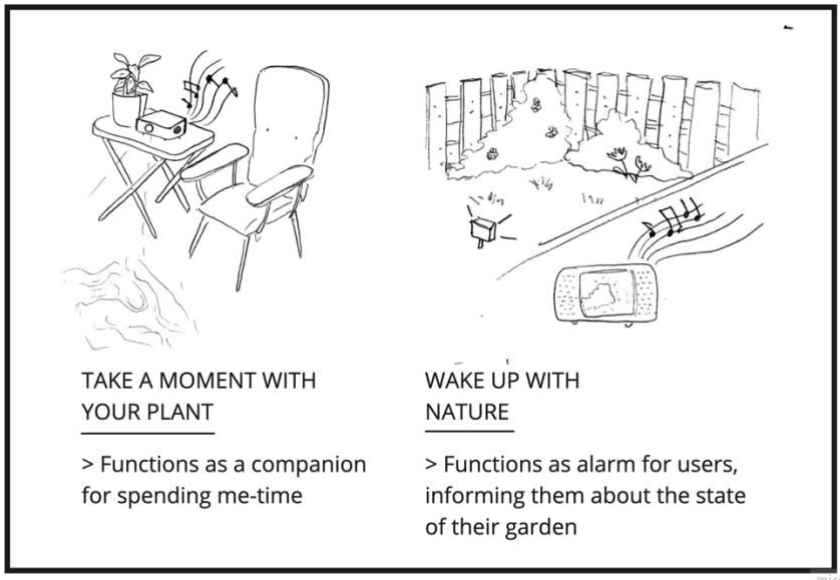

Figure 28: Two concepts derived from the iterative ideation process

By combining ideas and eliminating others based on these criteria, two concepts emerged: *Take a Moment with Your Plant* and *Waking up with Nature* (Figure 28).
In order to decide between the final two concepts, I evaluated them with the Amoebae wheel (Figure 30). However, based on this evaluation both concepts seem to have an approximately equal amount of potential. Because the assumptions regarding Waking up with nature generally consisted of things tested over longer stretches of time and only one concept could be worked out and tested within the timeframe, I decided to continue with Take a Moment with you Plant.

The concept consists of two parts: the sensor and the artifact. The sensor is wrapped around a house plant to read out the electrical potentials generated by the plant (Figure 32). These potentials can be looped through an oscilloscope which generates theremin-like sounds unique to each plant. These sounds can both be manipulated in volume, pitch, and tone by synthesizers (humans) and stimuli affecting the plant generating the electrical potential.

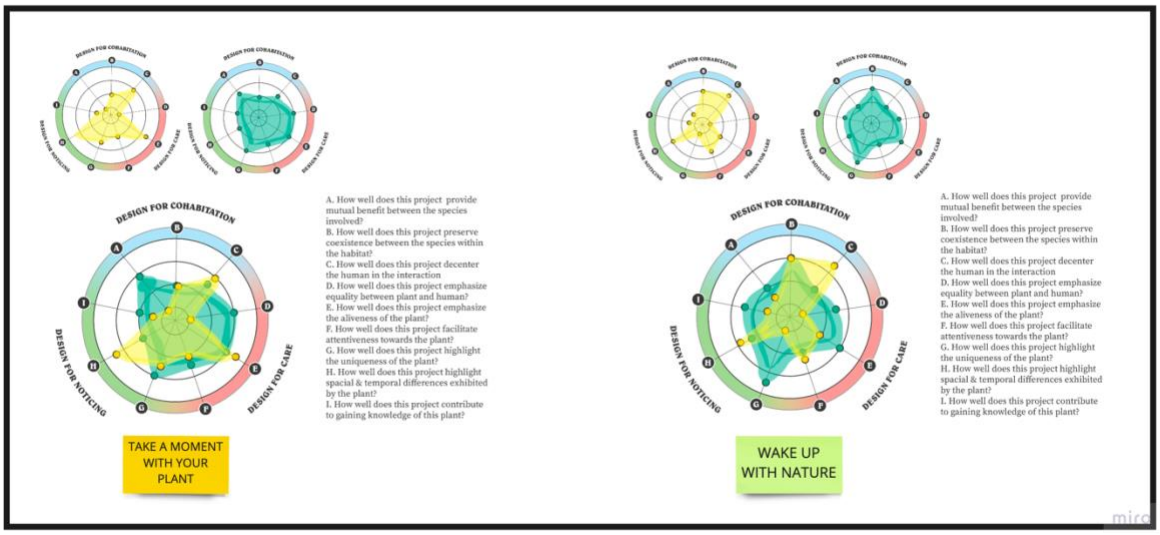

Figure 30: Evaluation concepts (green) and comparison with the initial idea (yellow)

The artifact functions as a medium between plant and human, where the electrical potentials generated by the plant are modulated to show a visual representation on a display alongside the audio that is generated based on the potentials (Figure 31). Inspired by Michael Seddon's *Wood-Wide-Web 1.0*, a visual representation seemed appropriate to add another dimension of aliveness to the plant. Additionally, the use of a display sets it apart from already established products such as the *Plant Wave.*

In order to emphasize the use of the concept as something that is shared between plants and humans, the console will activate its communication channel with the sensors when the user is near it. Meaning that to continually engage with the plant and artifact the user has to sit/stand next to the artifact, where it is encouraged to speak, sing, or hum. Since plants tend to develop better when exposed to music and possibly spoken word (Chowdhury & Gupta, 2015; Dodd, 2021).

Based on the concept a list of assumptions was made regarding the design principles and interactive expectations. From this list, four assumptions were selected to challenge during prototype tests. This selection was made based on two things: the relevance of the specific assumption to the role of the concept and whether it would be possible to test this within a short timeframe.

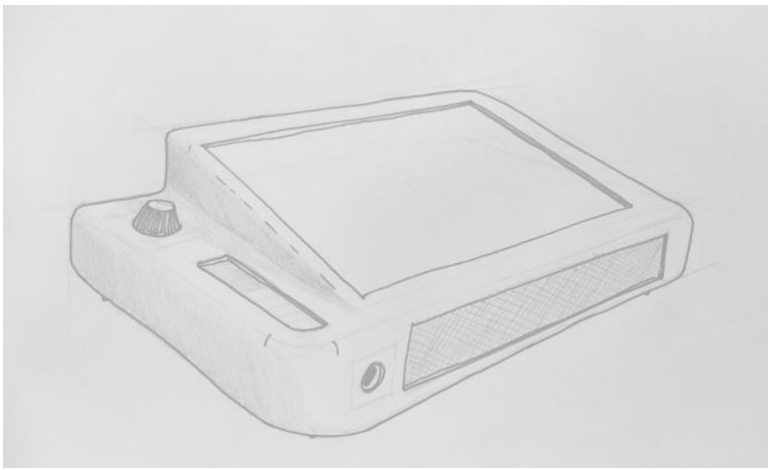

Figure 31: Console

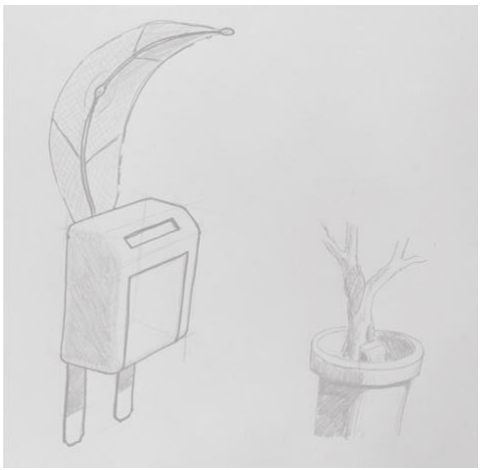

Figure 32: Sensing part

Based on this list, I wanted to address how well this prototype facilitates equality in the relationship, how well it addresses mutual benefit, and how well it shows aliveness. Since these qualities are the pillar stones on which the concept is built and improved. Additionally, I wanted to address a concern regarding the display, I expected the display to demand a large portion of the user's attention, effectively resulting in the plant becoming a medium for interacting with technology rather than the technology functioning as a medium for interacting with the plant.
Finally, the notion of interconnectedness needed to be addressed as well. Since this concept was built on facilitating interconnectedness based on perceptibility (the degree to which people acknowledge plants as being alive) this was covered by evaluating the aliveness.

Prototyping
Based on the assumptions described above and the framework described by Houde and Hill (1997) the assumptions could be divided into two categories role (equality and mutual benefit) and look and feel (aliveness and display). The assumptions with regard to the role were tested without a prototype.

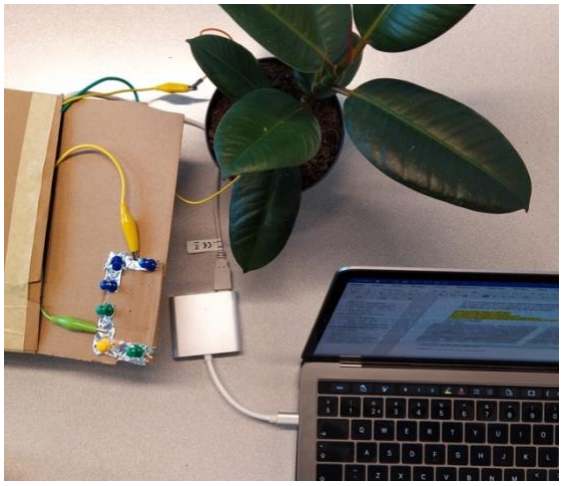

Figure 33: Wizard of Oz prototype

To address the look and feel assumptions a prototype was made using the wizard of oz method. The prototype consisted of two components: the husk and the output. The husk refers to all the elements that make the prototype seem like it works. It consisted of the representation of the artifact and a plant. The output refers to all the elements that make this prototype interactive. This included sound emitted from the laptop, a visual on the screen, and the software to make the sound respond to the wizard.

The husk was made from an enclosed carton box and a previously experimented with Arduino Uno prototype to seem functional. To further develop the illusion cables were plugged into the soil surrounding the plant and the Arduino was plugged into the laptop (Figure 33).

The output was made in Unity (2019.4.39f1). To give the "wizard" control, the position of the mouse was mapped to the pitch (x-axis) and volume (y-axis). The pitch depended on physical contact with the plant, while the volume depended on proximity to the artifact and plant as well as the "volume button" on the side of the artifact. A sample from another project regarding sound based on electrical potentials in plants (Christie, 2015) was collected and

looped as the main audio sample and a moving visual was made with Unity shader graph to be displayed during the test.

Testing
The concept was evaluated in two ways. A prototype was subjected to participant testing and the concept was evaluated via an in-depth peer review. The Prototype testing was meant to gain insight into plant-human interaction as well as to evaluate the look and feel assumptions mentioned above (Figure 34). The peer-review involved a video sample and an extended elaboration on the workings of the concept, to evaluate the role assumptions.

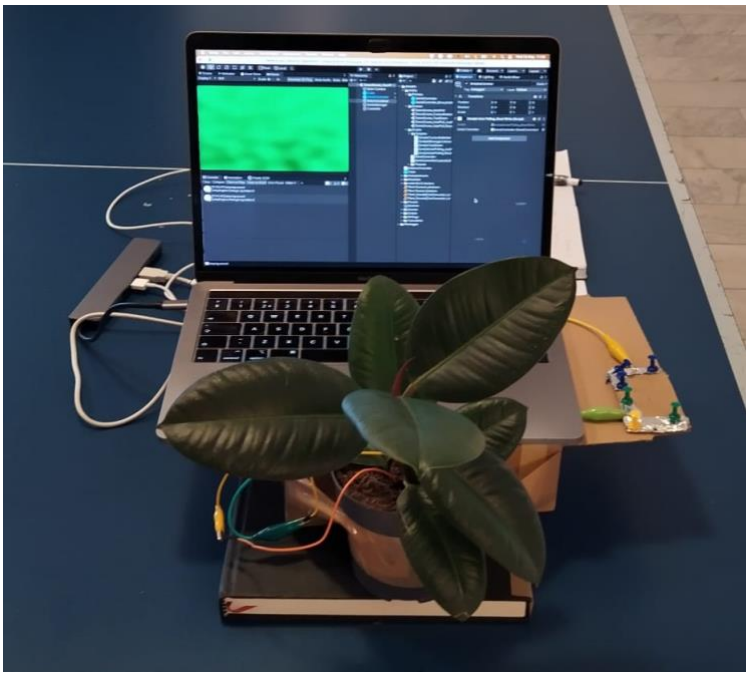

Figure 34: Prototype testing setup

During the prototype testing, five participants were free to touch the plant and experience its reactiveness to them through sound. This yielded several insights regarding the look and feel assumptions. Primarily, the introduction of sound turned the plant into a reactive entity. When asked about the aliveness of the plant, one of the participants noted: “sound does a lot; it adds an extra dimension to it”. Another participant also noted that the sound makes it feel more alive.
Additionally, several participants expressed that the sound also made the plant appear more fragile. With one of the participants saying that the sound made them care a bit more and that they were afraid of hurting the plant since the sound, seemed like screaming.
Furthermore, I observed that the participants barely paid attention to the visuals on the screen and all participants mentioned that they were most captivated by the relation between the touch and the produced sound.

For the peer-review, a speculative ecological design research intern was asked to comment on the concept. The peer-review started with an explanation of the concept and how it facilitates interaction between humans and plants, followed by a video from an existing project showing the interactive modalities of sound generated by touching a plant. After which a series of questions relating to the assumptions were posed to start a conversation. The insights regarding the look and feel assumptions largely coincided with those presented above. With regard to the role assumptions (equality and mutual benefit), the most notable insight was that

the current concept does not seem to have a perceptible mutual exchange. Furthermore, the needs of the plant are ambiguous, undermining the notion of equality in the relationship between human and plant.

All in all, the sound works as a good modality to emphasize aliveness, the display does not seem to be an issue with regard to drawing in all the attention, equality should be more emphasized by making the plant needs more explicit, and mutual benefit should be worked out further. In the next chapter, I will present the final concept that emerged from implementing these notions.

6. MAIN RESULTS & FINAL DESIGN

This project has manifested itself in two main design outcomes. The first is a concept and prototype that function as a contribution to more-than-human design and interaction design, the second is the Amoebae Wheel which may function as a tool for other designers wanting to evaluate plant-related projects adding to the more-than-human design toolbox.

Figure 35: Concept render

Take a moment with your plant

The final concept from this thesis project is a mediator between humans and plants (Figure 35). The main purpose of the concept is to facilitate a notion of interconnectedness with plants. This is done by emphasizing aliveness, maintaining mutual benefit, and supporting a relationship based on equality. The concept consists of four different actors: the human, the artifact, the sensor, and the plant.

Emphasizing Aliveness.
The aliveness of the plant is emphasized in two ways: A soundscape is emitted from the artifact and a visual is shown on the screen (Figure 36). The soundscape is developed based on the electrical potential that is registered by the sensor. Alongside the electrical potential, the sensor also registers the temperature, soil moistness, and light intensity. These have been proven to influence the electrical potential of higher plants. A machine learning algorithm is trained through the use of the concept to become more and more familiar with the plant the system is paired with. The algorithm can then inform the artifact of a reason why the electrical potential might have changed, resulting in a change of visual or auditive expression. The pitch of the plant potentials is shifted in accordance with a lack of moisture. A higher

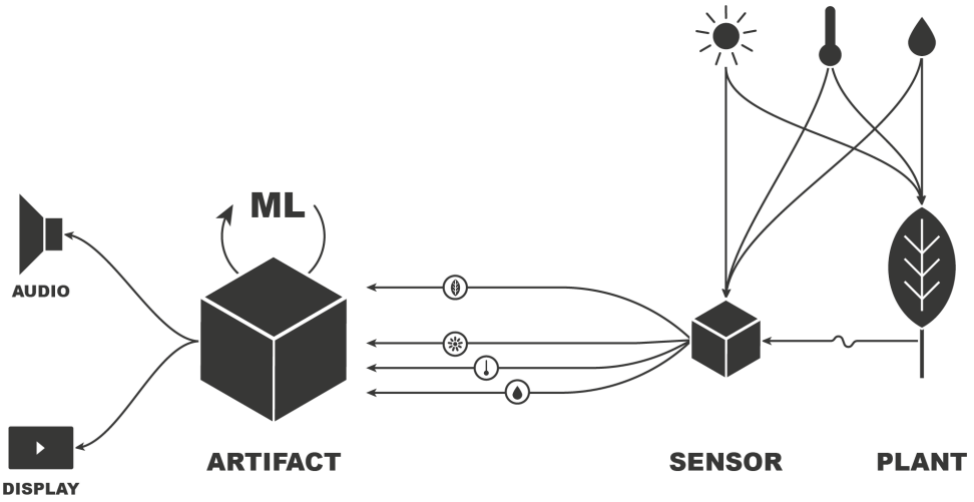

Figure 36: Concept actor relations

pitch signals the human that the plant is running low on water. The light intensity and temperature are variables that help understand the plant behavior but also form a somewhat random seed for parameters influencing the visual on the display.

Mutual Benefit
To facilitate mutual benefit, it is necessary to show what the different actors stand to gain from each other. The plant may receive water, nutrients, a better position in the house, or spoken words from the human. The human may enjoy a healthy plant and can be provided with soothing music. In order to maintain mutual benefit, it is necessary to exchange these desires for one another. As mentioned before, the sensor can both read out the state of the pot as well as the state of the plant, meaning that if the user neglects the plant, the system can cut off the services provided to the human.

Equality
Furthermore, equality in the relationship is maintained by emphasizing codependence. This is manifested in the plant calling for attention when in dire need of water. Similarly, the human can seek out the plant to access the services provided by the plant. A key feature is that proximity plays a large role here, meaning that humans can only access the sound once they are near the plants. This is also in line with Edwards et al. (2021) mentioning that time spent with nature positively impacts the notion of being interconnected with nature.
I would also like to point out that understanding the sound and reading out the display is supposed to be a skill. This means that users will become better over time anticipating different needs from the plant based on the sound it is producing.

Aesthetics
As an aesthetic choice, I decided to draw from the earlier mass-produced record players from the 60s and 70s. There are several reasons why I believe the concept is comparable to these record players. They were among the first to have been mass-produced and affordable for the middle class (Figure 37). Meaning that these record players most likely were the first to bring music into the homes of these people, marking the dawn of a musical life we are familiar with nowadays. Similarly, I suppose products like the *Plant Wave*, mark the dawn of another (somewhat less impactful) musical age, bringing the sound of plants into the homes of people.
Another interesting aspect is that these record players were made with the first commercially available plastics. All these bulky fillets and bevels were the result of manufacturers pushing

the limits of material tolerances (Figure 38). Similarly, new materials based on organic matter, that have been developed in the past decades are struggling with the same issues of high tolerances. I hope that by making this look fashionable again that the green alternatives to traditional plastics find their way into the market quicker.

Figure 37: 1970's Orange Philips 210 Portable Turntable/Transistor Radio (https://thegroovyarchives.tumblr.com/post/164212486082/1970s-orange-philips-210-portable)

Figure 38: Atari 800 (https://en.wikipedia.org/wiki/Atari_8-bit_family)

Evaluation

All in all, I believe the concept to be moderately accomplished. The project finds quite a solid theoretical grounding in the three design fields. However, since the concept is not based on a human-centered desire, it was hard to pinpoint what makes this product desirable. Furthermore, even though participants mentioned that the concept inspired a deeper connection with the plant, I am skeptical that this deeper connection is only limited to this specific plant. Further research is necessary to understand whether interconnectedness with a single plant also promotes interconnectedness with nature at large.
Additionally, the visuals on the display have only been marginally explored. participants showed little interest in the visuals of the prototype, but this may have been the result of aesthetic choices, therefore a study regarding the visualization of plant potentials is needed to find an appropriate visual representation.

The design process leading up to this concept was quite messy. Several reasons inspire this notion. Primarily, the process felt unguided. With which I mean that due to the nature of the project there was not an end goal to work towards, as is usually the case with user-centered design. This has left me meandering and exploring different tracks, quite a lot of which were not informative to the project. Furthermore, the emphasis throughout the project on literature research and material exploration left little room to collect empirical data, resulting in a lack of insights from the human standpoint.

My main takeaway for the next more-than-human design project is that I would narrow down on a location or species. This would allow me to make things like the material qualities explicit sooner in the design process. Furthermore, this project has taught me that the slow-growing speed of plants is a characteristic to keep in mind when facing projects with a relatively short timeframe.

Design for Plants evaluation tool: Amoebae Wheel

The Amoebae wheel is the second outcome of this thesis (Figure 39). This outcome is the result of addressing the lack of tools within more-than-human design. The tool allows designers to evaluate ideas, concepts, and projects concerning the three design fields that have been found influential in creating a good more-than-human design project, tailored to designing for and with plants. Arguably, this model can be applied in any design project involving plants. However, I would strongly argue that this model is most suitable for the HCI and Interaction design community due to the model's emphasis on interaction. A complete version of the Amoebae wheel with explanations can be found in Appendix F.

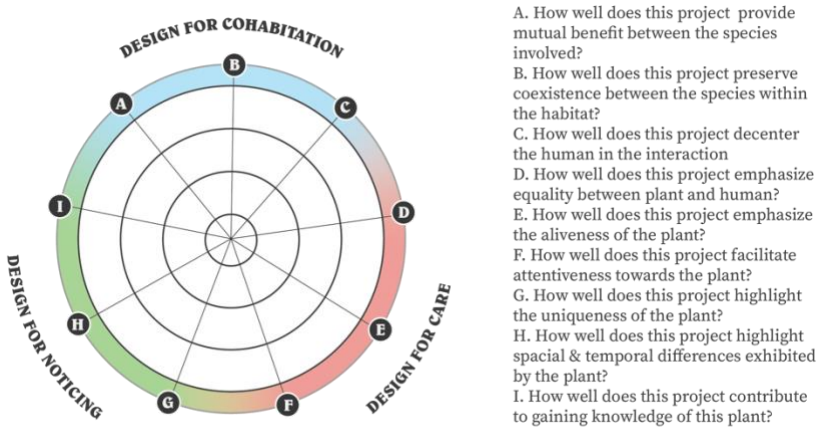

Figure 39: The Amoebae Wheel

Evaluation

All in all, I believe that the process leading up to this model has been satisfactory. The model has been tested several times throughout the project, during which I always made sure to take notes regarding comments or critiques, to further feed into the development of the tool. The design principles which informed the model have also been grounded in the background literature, addressing the three design fields and interconnectedness with nature. Furthermore, I believe the participatory design approach adopted during the Speculative Material Probing workshop was especially informative for developing this tool.

However, even though the model has come from a rich theoretical background, I believe that the model needs further development. There are two main reasons for this. Primarily, the model is based on a literature study and some iterations over the span of nine weeks. Arguably, to truly understand what makes up the different design fields, more time and knowledge are necessary. Furthermore, I am under the impression that the three design fields have the potential to be developed into a more-than-human design evaluation tool, rather than a tool just focused on designing with plants.

Contribution to More-Than-Human Interaction Design

This project contributes to the more-than-human design field with a concept that draws from different design examples within the scope and background theory as well as a “design for plants” evaluation tool that can aid other designers in evaluating plant-based projects. To make the contribution more explicit I will address the research questions which were presented in the Introduction.

Interconnectedness
The eventual concept shows an attempt at merging interactive technology to strengthen the notion that humans are situated in the biosphere. This was also partly tested during the prototype testing. Which showed that interactive technology can aid the notion of interconnectedness by introducing an element of response to the plants. Furthermore, the Amoebae wheel is a tool that was developed for emphasizing interconnectedness.

Care for non-Animals
The concept also promotes care towards the plant involved with the artifact. Additionally, we saw that the participants expressed that using sound as a reactive medium also changed their perception of the plant, being more cautious and tender with it.

More-Than-Human Voices
Finally, the concept also makes sure to address benefit for humans, albeit in the form of mutual benefit. The process shows that even when something is not developed with human-centered problems in mind, it can still be beneficial to humans.

7. DISCUSSION

In this chapter, I will discuss some topics that are of special interest to the field of *More-Than-Human Design* but may have not been sufficiently addressed in this thesis project or need extra clarification in the form of a reflective standpoint.

More-than-human Knowledge & Time Constraints

Obtaining knowledge on the topic of more-than-human design proved to be harder than I anticipated, to become familiar with the more-than-human terminology I was necessitated to draw from other fields such as Anthropology, Urban Development, and Citizen Science. Having a lack of base knowledge regarding the topic, also made it hard to judge other more-than-human design projects. A great deal of the allocated time went into doing literature research and material exploration, which inevitably left little room for empirical data collection from target audiences or stakeholders. This left me to mostly generate insights based on autoethnographic practices. Reflecting, I believe that it would have been beneficial to either have spent time researching people in close interaction with plants, narrowing down the topic from the start, or do interviews with experts in the field to gain knowledge, instead of doing a literature review.

Capitalocene

I would like to mention Jason Moore's *Capitalocene* as a substitution for *Anthropocene*. The term suggests that capital has had a large effect on the distribution of pollution, with the rich polluting more than the poor. According to Moore, the term "Anthropocene" flattens out this notion and accuses all people, placing an extra burden on those who have been duped by the actions of others (Moore, 2017). Building on this notion Vergès (2017) writes: "Adaptation through technology or the development of green capitalism has indeed, been presented as a good strategy. Yet it does not thoroughly address the long history and memory of environmental destruction […], nor the asymmetry of power." Even though I have advocated for bridging the gap between socio-cultural issues and issues within natural sciences, I have not been able to address this during the ideation process or the conceptualization. Therefore, I would suggest that to extend this work more research has to be done concerning the socio-cultural implications of the more-than-human design diagram.

Care

Furthermore, I tried to adopt a notion of care into my process. From the second week of this project, I have been tending to an array of different plants, making sure they have enough water and shade before leaving for the weekend. During the *Living, Dead or Artificial* workshop I was put in an awkward position, where one of the participants started snapping branches and leaves to see if they were real. This inevitably led me to cut this part of the research short. In the speculative material probing workshop, I made sure to notify people of the fragility of the plants. This workshop in particular was imbued with care, as I had carefully set up the workshop space and made sure to test all the generative materials before using them in the workshop. It was therefore especially heartwarming to receive positive feedback from almost all users on care put in the workshop.

Another way, I tried adopting care into the project was by avoiding companies that have notorious care ethics, such as the online webshop amazon. Although I do not have regrets about adopting this strategy, this has led to me receiving certain resources and materials a lot later than expected, slightly delaying certain activities, mainly with regard to material exploration.

Finally, I also have tried to combine a form of self-care and project care, by trying to write a small reflection every working day, reflecting both on my accomplishments and to-do's as well as my insights. Generally, they helped to keep the week structured and also to make sure that I had moments where I was able to take a step back from the project and see what I had accomplished so far.

Noticing

In addition to the daily reflection, I was inspired by both the "biodiversity logbooks" of Edwards et al. (2021) and Darko Aleksovski's book *Growing* (2016). Which led me to make sketches from plants I encountered throughout the city of Malmö. These sketches were not necessarily made for any research purposes but just to imbue attention into my life outside of the project. Even though the sketches I made took a very crude form, I noticed that my mind started orienting itself to "noticing" more plants. Seeing specks of green growing through the cracks of the pavement (Figure 40). Interestingly, this made me reflect on how sensitive I am to plant blindness and how easy it is to filter plants out of a scene. It became more apparent to me that nature and culture do exist together. Embracing this notion and not just intellectually knowing it facilitated a more internal awareness of nature.

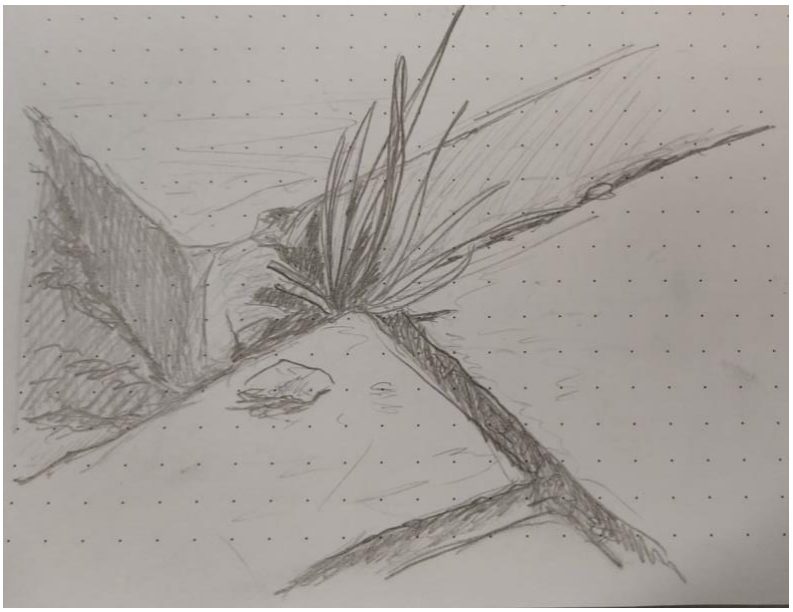

Figure 40: Drawing made to practice noticing

8. CONCLUSION

All in all, the literature and canonical examples have shown that more-than-human design has potential in addressing socio-technical issues. However, the field tends to remain obscured, and projects tend to stay conceptual. By looking into the three design fields: *Design for Care, Design for Cohabitation,* and *Design for Noticing* we have seen that user-centered design is not the only way to produce artifacts beneficial to humans. From the interaction design perspective, combining the natural world and interactive systems may inform an array of interactions currently overshadowed by industry pursuits.

Through the project, we have seen that combining interactive technology and plants can aid in reflecting on one's relationship with plant life. It has been theorized that the notion of interconnectedness with nature can be achieved through the different design fields by paying attention to either increasing the internal association of the self with nature (mentally), the increase in knowledge about the biosphere (intellectually), or the acknowledgment of nature being alive (perceptually).

To develop this project further, more research regarding the materiality of electrical potentials produced by higher plants and which needs they convey should be done to better address plant needs. Furthermore, long-term engagement should be tested to see if the notion of interconnectedness with nature diminishes, fluctuates, or increases over time.

I would like to conclude this thesis by emphasizing the urgency of listening to more-than-human voices, especially now that our cities become hotter, the weather more unpredictable, and our biodiversity is diminishing. Listening to more-than-human voices might just make the world more habitable.

“Even if all the trees return,
it won't be his forest anymore.
The Great Forest Spirit is dead now.”

“Never.
He's life itself.
He's not dead, San.
He's here right now,
trying to tell us something,
that it's time for us both to live”.

Princess Mononoke (1997)

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APPENDIX A: Dictionary of Working Definitions

This appendix has functioned as a reference guide for myself, to know what exactly I mean when using different jargon. Furthermore, I have included it for the reader to maintain a similar purpose. I hope this will help the reader understand what I write about and that it will shed light on my perspective regarding the project. I would also like to emphasize that I am aware that most of these words and phrases have different meanings in different disciplines, therefore it is important to view these working definitions not as a universal truth, but rather as a necessity to make this project more comprehendible for myself.

Anthropocentrism

Anthropocentrism refers to the predominant view on, in this case, nature, fed by a mainly western ontology that nature is an expendable resource, which can be capitalized on.

Human-Computer Interaction (HCI)

The field of Human-Computer Interaction (HCI) concerns itself with the interactional qualities of computing artifacts and systems. For me, this means that HCI is inherently linked to computation and most probably digital computation. I see this as a range between new back-end implementation for smooth data transfer to user interface design, meaning that it can both have indirect and direct implications for the end-user. Although a large portion of Interaction Design is situated within this field, I view Interaction Design as something that also exists outside of HCI, in the way that Interaction Design can also address interaction qualities of non-computing artifacts and can address more socio-cultural issues involving materials and knowledge outside HCI

Interaction Design

To me, it encompasses all interactions facilitated through or by computing components.

More-Than-Human Design

In light of this thesis, More-Than-Human Design refers to design that deliberately acknowledges different more-than-human voices, extending the notion of decentering the user. more-than-human voices in this case can also refer to non-cultural voices such as microbe colonies, climate change, and a specific mushroom.

Non-Animals

The working definition I use for non-animals refers to all organisms that are not within the animal kingdom, meaning that with this notion I refer to plants, fungi, micro-organisms, yeasts, etc. However, this project is mainly concerning plants. This also means that I am excluding inanimate actors such as soil, a river, or rocks.

Posthumanism

In some cases, “Posthumanism” and “More-than-human” are used interchangeably. I would like to distinguish between the two, where posthumanism refers to the research area within humanities studies concerning itself with moving beyond humanity, while more than human, in the case of this thesis, refers to a design practice incorporating design voices outside of those presented by humans.

APPENDIX B: Complete Design Collection

This appendix functions as further reading for Chapter 2: Current state of the field. Here I have collected, what I would like to call boundary projects within the domain of more-than-human design with plants as actors. These projects operate more or less on the fringes of this domain and together form the state of the art. This appendix consists of two parts: the first being the synthesis drawn from the fourteen projects (Figure 41) and the second being an elaboration of these fourteen projects, by providing a description, the relevance for this thesis project, the takeaways for the synthesis, and a critique.

Synthesis of the Design Collection

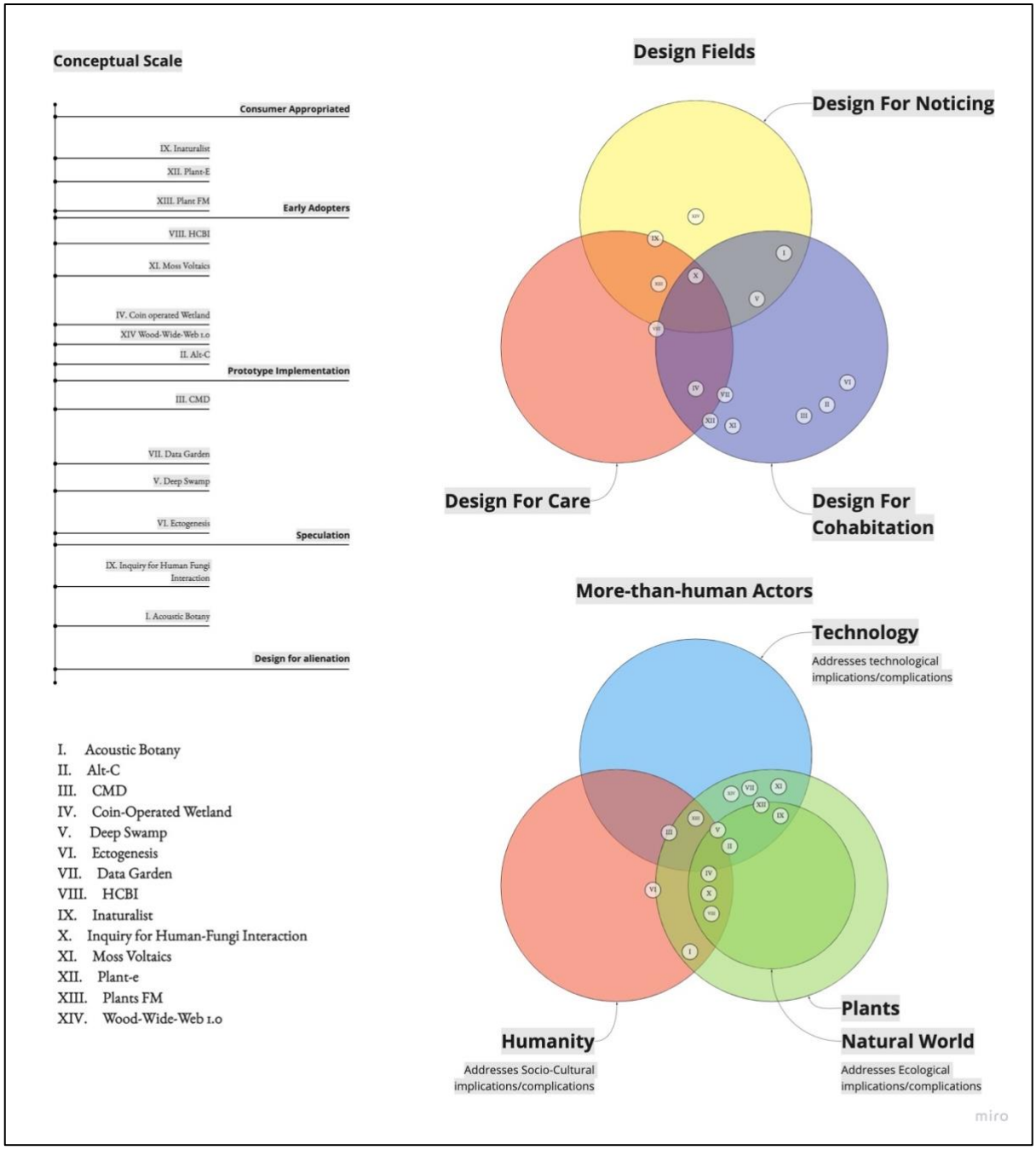


Figure 41: Synthesis of Design Collection

Acoustic Botany & Silvery Acres

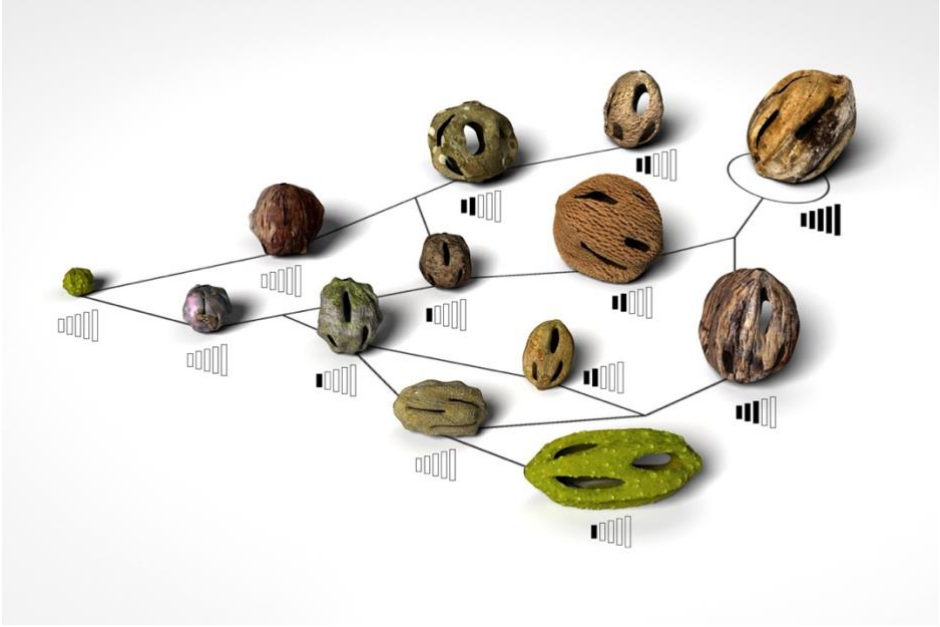


Figure 42: Musical seed pods (Benqué, 2010a)

Description
David Benqué's *Acoustic Botany* is a project that takes genetic manipulation for the benefit of aesthetics to the next level. The speculative design project is trying to open up questions on the topic of synthetic biology (Benqué, 2010a), by conceptualizing plants that make music (Figure 42). The *Silvery Acres* project is a follow-up installation showing what these aesthetically engineered musical plants might form together (Benqué, 2010b).

Relevance
This project, although not necessarily linked to HCI, shows how conceptual design can also aid in envisioning futures with socio-cultural changes. This project sets out to open up a conversation on the cultural implications musical plants might have, not showcasing the latest technology per se.

Takeaways
What I like about this project is that its main purpose is not about technological advancement and or showing where the state-of-the-art technology can bring us, but rather what would happen if it were something established already.

Critique
The project has a lot of potential in bringing socio-technical issues and challenges together, but this seems to be left open. Of course, this can be a deliberate choice, but I think it would have been interesting to see these issues being unpacked, to make the whole project larger than an aesthetic exhibition experience.

ALT-C

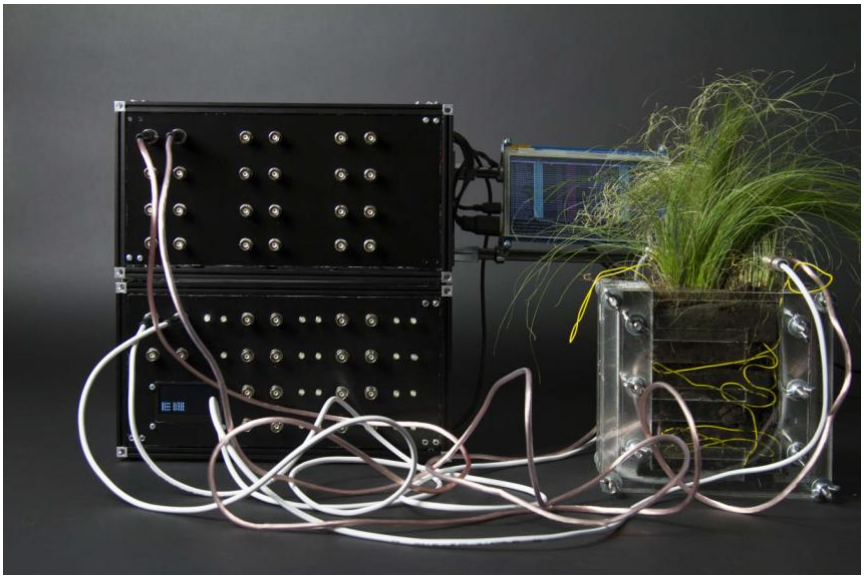


Figure 43: Bio photovoltaic cell with single-board computer (Sedbon, 2018a)

Description
This conceptual design project uses bio photovoltaic technology to supply a small computer with enough energy to mine cryptocurrency (Figure 43). Since photosynthesis, the driver of bio photovoltaics can be linked to the atmospheric condition, the author draws a correlation between the atmosphere and cryptocurrency production. Effectively, Sedbon hereby envisions a future where climate change influences the market, as the AI running the program will invest its profits into green projects (to stimulate a better atmospheric condition), expanding its capacity to produce more currency (Sedbon, 2018a).

Relevance
What is interesting about this project is that the AI, in a sense, becomes a voice for the world of flora. It influences our capitalistic system through the rules associated with its created consumer market while advocating for the more-than-human. In theory, the system could even see humans as unwanted commodities.

Takeaways
In my opinion what is interesting about this project is that it creates an assembly of actors, where humans are not in the center.

Critique
One of the things I believe undermine the project is, that in the end humans dictate what is right and what is wrong, they provide the initial conditions for the AI. Furthermore, the AI reduces plants and green investment programs to mere materials for its desired better atmosphere. If the AI could find a way of replacing the plants with a more effective producer of better atmosphere it would render them obsolete. In one way instead of creating a human-centered project, the project has become an AI-centered project, having created an AI that operates out of (programmed) egocentric drives, which mimic a lot of the functionalist views of early western ontology about controlling nature.

CMD

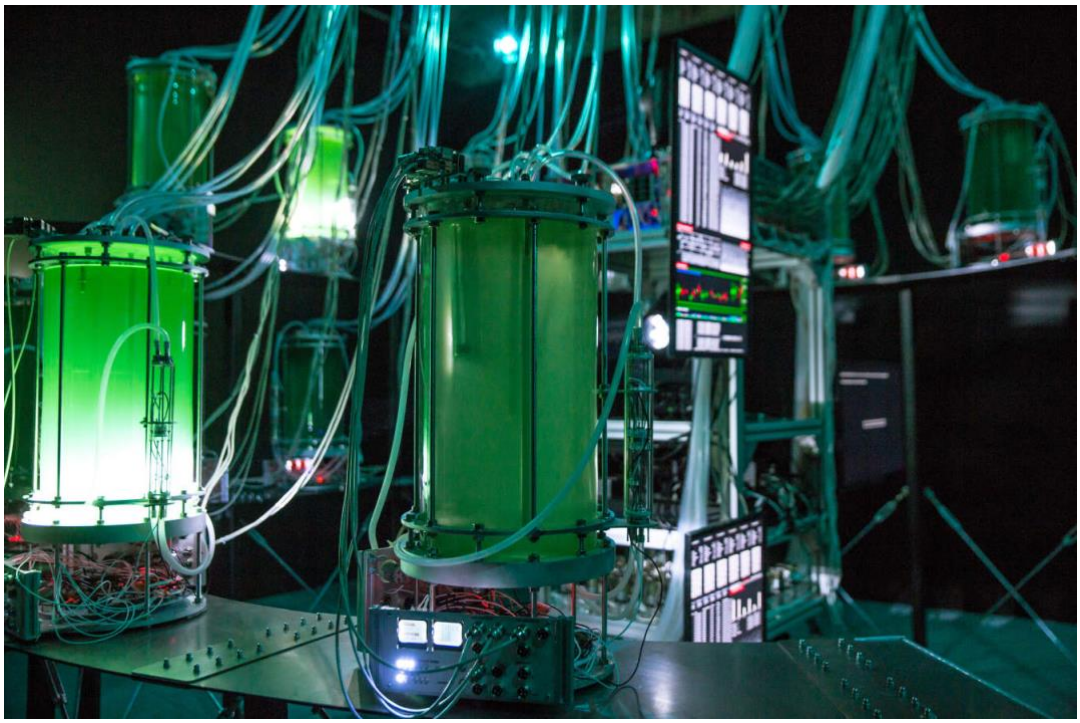


Figure 44: CMD set up with cyanobacteria tanks and light sources (Sedbon, 2020)

CMD is a project that creates an experimental setup where politics and ecology collide to provide a speculative view of how biology in recent times has become a major influencer in the software world (Sedbon, 2020). In this project, Sedbon created a setup where two competing cyanobacteria colonies compete with each other for access to a light source (Figure 44). The project shows how on the micro-level the bacteria produce offspring which has consequences on the macro-level of the behavior of the culture.
With this project, Sedbon reminds us of the words by Harraway (1991) explaining that humans are technological and that this is a part of our nature. This means, then, that our tools, like computers and software, are a cultural and material extension of ourselves. He shows us that the political, cultural, and artificial are inherently connected to the natural and living. In this project he acknowledges nature's place in society, providing a good critical example in this context.
To me, this project shows that even without the direct engagement of humans, interactions can emerge between more-than-human actors.
However, I do believe that the project casts nature in the role of an actor in an artificial system, meaning that it does not necessarily acknowledge a living will relating to the saying "nature finds a way".

Coin-Operated Wetland

Figure 45: Laundry machine running on a wetland (Brain, 2011)

Description
This project uses small patches of wetland to create clean water for a laundry machine (Figure 45). The project aims to have people reconnect with nature and to show that ecological benefits are necessary for human survival (Brain, 2011). About this project Brain says: “By directly connecting human action with environmental health, the work poses questions around ecology, co-existence, and the culture of engineering.”. Through which Brain is essentially advocating for a voice of nature.

Relevance
With this project, Brain acknowledges ecology as a part of our existence. Seeing her project as something between ecology, engineering, and art, she is starting to bridge the gap between natural and cultural sciences (Brain, 2011).

Takeaways
In my opinion, this project situates plant life well into a cultural context and shows the audience how nature and culture could come together. It raises interesting questions about co-existence and cohabitation. This project among others, have led me to realize that a strong driver for designing for cohabitation is actually mutual benefit.

Critique
Although this project sheds a light on plants and their place among humans in a possible future, I have a strong impression that this project is still focusing on instrumentalizing the wetlands. Furthermore, the project is made as an exhibition piece, and as such it does a really strong job; however, I would imagine it being maybe even being more impactful as part of an actual laundry shop. What I am trying to say is that at this point it lacks engagement with people their lives, it stays confined in the space of art.

Deep Swamp

Figure 46: Deep Swamp exhibition (Brain, 2018a)

Description
Deep Swamp is an installation that sets out to raises the question of; if preservation of ecologies means maintaining ecological processes, what would it mean to have computational systems take on their voice? (Brain, 2018a). The project consists of a piece of wetland and three AI's. One is tasked with maintaining a natural environment, a second with producing a piece of art and a third who "just wants attention".

Relevance
What is interesting about this project is the interaction that happens between nature and technology. Only having a system maintain the ecological balance would mean decentering the human, maybe even alienating them. However, maintaining an AI that seeks human attention draws them in as a third party.
Furthermore, what stands out is the expectation that humanity is aware of what maintaining an ecology looks like by implementing a system that cares for it. A system is reliant on human programmers to set ground rules. By this the project raises critical questions about the optimization of natural assemblages.

Takeaways
This project definitely has strong aesthetic qualities which might aid in making lasting experiences. Furthermore, it has an interesting manner of dealing with the nature-tech-human triangle.

Critique
By introducing an AI that desires to create art, turns this piece of wetland in something that should be seen, something that should generate an audience and is inevitably being used for humanities entertainment. I don't think this underlines the relevance of plants within an ecosystem that well.

Ectogenesis

Figure 47: Plant embryo's grow, altered by human sex hormones (Petrič, 2022)

Figure 48: Data Garden Set up for sequencing DNA (Data Garden, 2020)

Description
This project aims to accentuate the boundaries of synthetic biology. The artist used one of her own sex hormones to genetically alter plant embryo's. This has created a unique plant-human hybrid that is built on her own genetic contribution (Petrič, 2022) (Figure 47).

Relevance
Although, not situated within the field of HCI, this project raises interesting questions on socio-technical concerns regarding gene manipulation and a possible future where this is normal.

Takeaways
Exploring these boundary issues and raising questions about ethicality helps people envision a world they desire or repulse. Similar to speculative design projects, this project shows a future people should bear in mind and helps them shape what they desire and don't desire.

Critique
Although, this project raises interesting cultural questions the voice of technology and the natural world remain rather limited. It further feeds the notion that humans control nature and situate themselves above it.

Data Garden

Description
Data Garden is a project that aims to unify people, ecology, and technology, this is done through data storage by storing information in the DNA sequences of plants (Figure 48). Effectively this would mean that a forest could become a data center (*Data Garden*, 2020).

Relevance
The project raises interesting questions with regards to exchanging metal storage systems with carbon-based ones. Furthermore, the project also situates itself on the intersection point of socio-technical issues regarding design for ecology.

Takeaways

It is interesting to see how care for plants will be associated with caring for one's data, giving completely new meaning to caring for the natural world.

Critique
The main critique for this project has to be the instrumentalization of plants, burdening them further as being tools to do something. Even though, the caring element is really strong, it does not actually lead to more climate-conscious people.

Human-Computer Biosphere Interface (HCBI)

Figure 49: Human-Computer-Biosphere Interface system (L), Remote system (R) (Kobayashi et al., 2009)

Description
The Human-Computer-Biosphere Interface (HCBI) is a garment that reflects different recordings from a remote wild environment (Figure 49). The system aims to reconnect people with the natural world, by allowing users to interact with the natural world in a non-destructive manner (Kobayashi et al., 2009).

Relevance
This project gives a voice to the forest, by saying that even ecotourism is a capitalistic form of destroying nature under the premise of good morality. The project raises questions about how much of human desires should be factored into more-than-human designs.

Takeaways
In my opinion, the project has found an interesting way of juggling human desires to enjoy nature with nature's desire to not be disturbed. It has found a nice balance between cohabitation and care, without instrumentalizing nature to the extent that it cannot be seen as a separate entity.

Critique
What would be interesting to see is whether this, in the long run, can replace real life experiences with the natural world. I believe that in order to take up the natural world in the self, like suggested by Schultz (2000), one has to have some form of actual and meaningful experience with nature. Furthermore, the project contributes to the idea that culture and nature are separate entities for uninformed people.

Seek

Figure 50: Seek application to recognize plants and animals (Seltzer, 2021)

Description
This phone application allows users to scan animals and plants (Figure 50) (Seltzer, 2021)

Relevance
The product and surrounding community aid the notion of reconnecting with nature as well as helping users to notice what is around them. The application can be seen as an amplification of existing human capabilities in order to get a better grip on the natural world around them and create interesting encounters between individuals.

Takeaways
Amplifying human abilities that foster connection with the design fields: noticing, care, and cohabitation, can function as a good means to create meaningful encounters. Using interactive technology to do so makes this especially easy. Furthermore, it contributes to science done on the local environment. Crain et al. (2014) argue that this form of citizen science can lead to more affinity towards the local ecosystem.

Critique
Again, drawing from Crain et al., (2014), this project/product could benefit and enlarge its meaning to humanity by also including socio-cultural research topics. Right now it just contributes to the collection of data points in natural sciences without cross-referencing socio-cultural trends.

Inquiry for Human-Fungi Interaction

Figure 51: the hand-substrate interface from an inquiry in human-fungi relations (Liu et al., 2018)

Description

This project explores design for noticing and cohabitation through designing for collaborative survival (Liu et al., 2018). The project is an assembly of three parts, all three providing a different experience to the user and the more-than-human actors involved. One of the projects is the hand-substrate interface, which aims to bring the user as close as possible into experiencing fungi, both how they experience the soil as well as coming into touch with them (Figure 51).

Relevance

The project explores what it means to share the planet with different species and how we can pay attention to those surrounding us. It aims to help both humans, by foraging for mushrooms, as well as the forest, by spreading spores and cataloguing its health.

Takeaways

Here it is interesting to see how citizen science can contribute to all three design fields: noticing, care and cohabitation. And how mutual benefit can actually be an outcome of a project. It shows interesting use of interactive technology aiding the relationship between human and nature, taking the shape of a translator (almost) instead of pushing technology in the role of "voice of nature".

Critique

Although, the project raises some socio-cultural questions of cohabitation, it doesn't dive deep into the implications of how this could translate into urban environments or could be appropriated by other designers.

Moss Voltaics

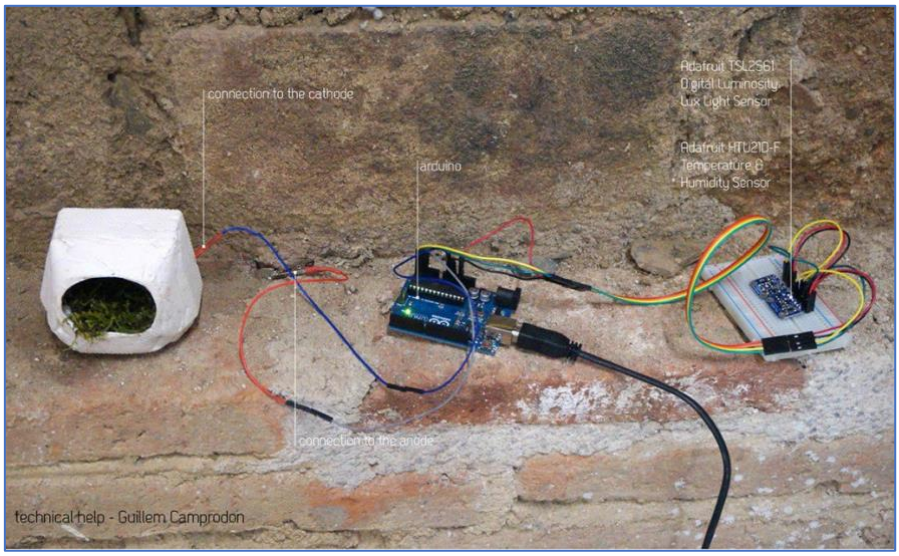


Figure 52: Example set up Moss Voltaics (Moss Voltaics - The Institute for Advanced Architecture of Catalonia, 2018).

This project experimented with an emerging technology called bio-photovoltaics (BPV) to create urban facades that also function as a source of green energy (Figure 52). This technology utilizes the capability of plants to photosynthesize in order to create a positive and negative pole which can then be used to charge batteries or electrify artifacts, basically functioning as a standard solar panel (*Moss Voltaics - The Institute for Advanced Architecture of Catalonia*, 2018).
Even though the project is not directly linked to Interaction Design it is interesting to see how the authors have appropriated to urban development. The usage as moss as a material to design with, rather than a substance that should be mitigated when designing buildings, and to turn it into something functional on multiple levels strongly ties into the notion of naturecultures (mentioned earlier. How it ties to this thesis, is that it provides an interesting example on how to combine electronics and living materials, as well as acknowledging the city as an ecosystem. Even though, the authors do not necessarily mention this, I can see how the use of the modules could contribute to increasing biodiversity in densely populated areas, with all its. An issue that might arise from this project is that it might instrumentalize the moss, meaning that humans will see it as a tool and not a living thing situated in the grander biosphere.

Plant-e

Figure 53: Plant-e energy cells (Luleva, 2015)

Description
Plant-e is a company that provides bio photovoltaics (BPV) components as a commercial good. The company's main focus is providing a renewable energy source, mainly to developing countries, while promoting ecological diversity and maintenance (Figure 53.

Relevance
Although the project is not necessarily interactive, this is one of the first commercially available products utilizing BPV. For me, BPV is one an interesting and unique material property of plants and their symbiotic relationship with microorganisms. Maintaining BPV production requires balancing out different more-than-human voices.

Takeaways
The main takeaway here is that combining technology and the natural world is something that can fit within a capitalistic market. Further showing that maintaining ecological diversity can fit within our culture.

Critique
For this project a critique can, be that it poorly fits with interaction design, however the underlying implications of cohabitation and maintaining ecological diversity fit really well with this project. One of the issues I do encounter with this product is that it instrumentalizes nature under the name of natural protection. Similar, to what Kobayashi et al. (2009) explain in their paper about ecotourism, questions can be raised about what is done for species that do not fit this model or what the implications are of maintaining an energy plant in an national park for instance.

Plant Wave

*Figure 54: Plant wave hooked up to a plant (*Plant Wave, *2020)*

Description
Plant wave utilizes electrical potentials generated by plants to create unique musical compositions (*Plant Wave*, 2020). It is a consumer available product in the form of a small electrical box that can be hooked up to plants with two electrodes (Figure 54).

Relevance
This product is interesting since it capitalizes on a unique material quality of plants. Furthermore, it stimulates to spend time with plants and generates a new kind of appreciation for plant qualities that otherwise go unnoticed.

Takeaways
What strikes me most is how this brings people closer to plants and shows them a way of experiencing plants in a new manner. I believe this project shows a good approach to designing for care and noticing and facilitates unique and memorable experiences like Hecht et al. (2019) mention.

Critique
I see how this contributes in seeing plants as part of the ecology surrounding people and although I do not see real critiques I would raise the question of how this will influence having plants at home versus keeping them in nature.

Wood-Wide-Web 1.0

Figure 55: Wood-Wide-Web 1.0 set up (Sedbon, 2018b)

In this project Michael Sedbon aims for aestheticizing communication between plants (Figure 55). Aestheticizing the communication allows for humans to experience unseen interactions between plants that might seem to most as inanimate or still (Sedbon, 2018b). For me this project ties into combating plant blindness in the sense that it helps people to see that plants are more than mere artifacts of nature. Furthermore, it helps with creating awareness among people that ecology can be seen as an intricate web of interdependencies, even though those might not always be apparent. I hope to incorporate the aestheticizing of more-than-human communication, however my aim is to also include the human more in this process.

APPENDIX D: Speculative Material Probing: Exploring More-Than-Human Design Tools

Workshop Materials

As mentioned before, one of the reasons of conduct for this workshop was related to testing different tools for more-than-human design and assessment. Therefore, I presented the participants with an array of workshop materials they could use to inform their idea. The tools I used for this workshop were:

- Speculative Future Narrative
- List of living material characteristics (in the form of a presentation slide)
- Design field cards with *How might we's* based on the assessment framework
- A tabloid template with prompting sentences
- A physical plant

I also provided some cookies in order to create a more informal setting as some participants did not know each other. Figure 56 shows all the materials.

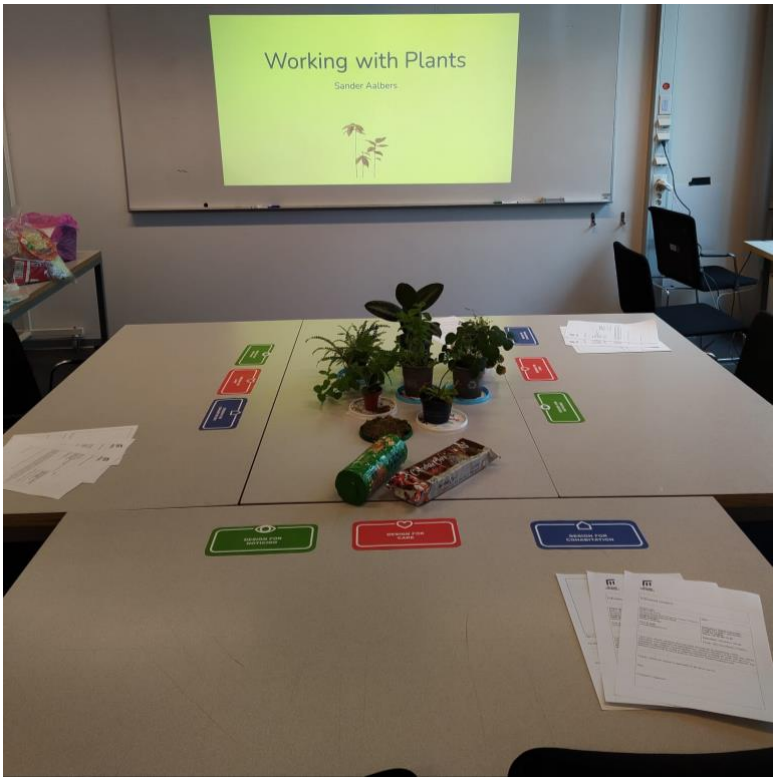


Figure 56: Materials used in the Speculative Material Probing Workshop

Manner of Conduct

The workshop was planned to last one hour but ended up taking one hour and fifteen minutes. Therefore, I would like to revise the planning for future use of this workshop setting.

Make groups & choose plant	5 minutes
Listen to narrative	10 minutes
Ideate	30 minutes (initially 25 minutes)
Evaluate	30 minutes (initially 20 minutes)

"In this research I am exploring materiality of different kinds of artifacts. In order to do so I would like for you to wear a blindfold. After you've put on the blindfold, I will provide you with a short narrative. While I'm speaking, I would like for you to imagine visually what I'm narrating. After the narrative, I will provide you, one by one, with different materials. You will create a story of function around these materials according to the narrative. After which

we will remove the blindfold and have a brief discussion, and some follow-up questions. Are you ready?
Two reasons: informing my ideation and checking on the usability of the more-than-human evaluation tool.

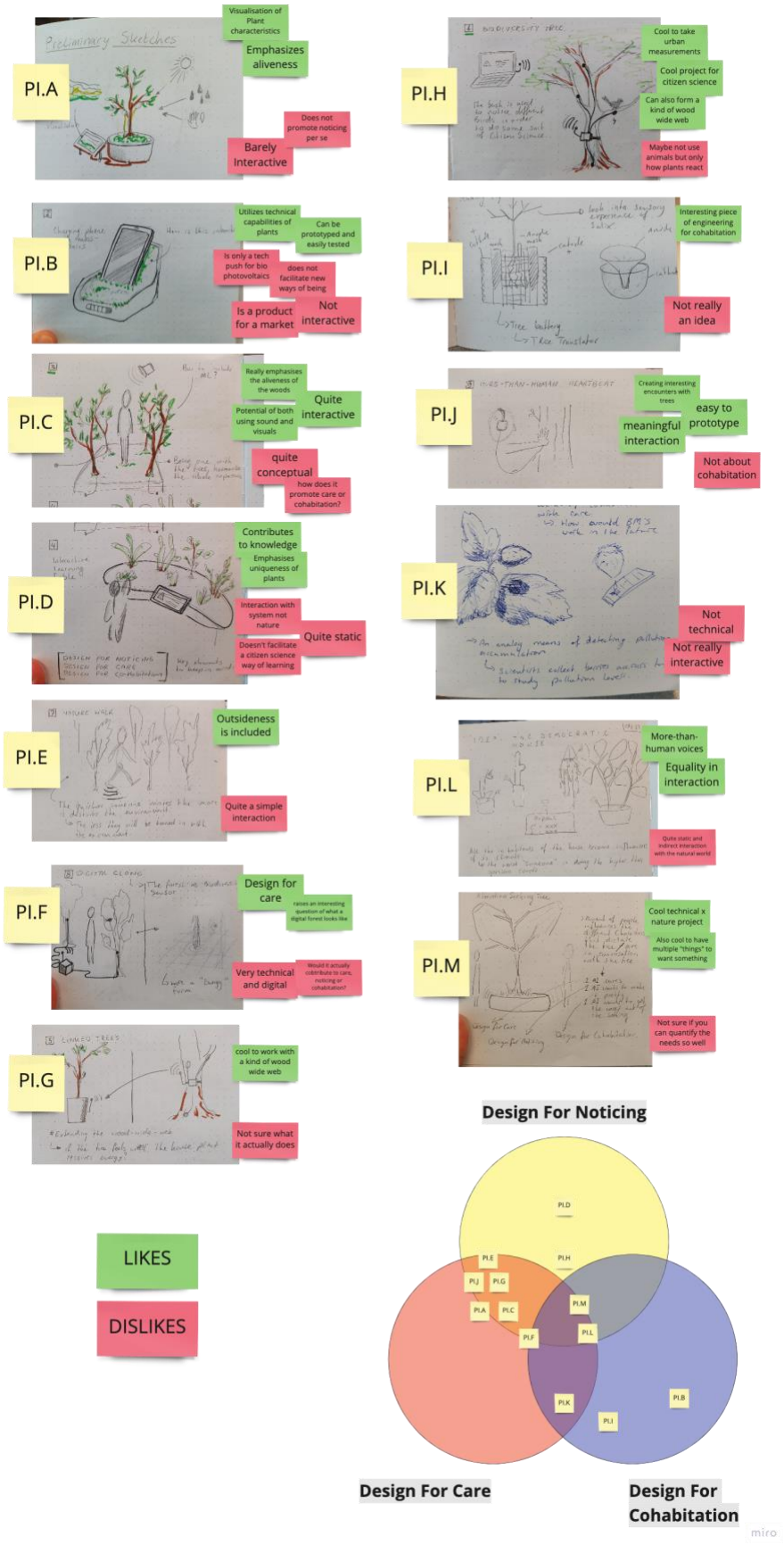
"30 years have passed.
You wake up, feeling rather nostalgic.
So much has changed since your time in university.
You step outside your home into the concrete jungle that is now the city you live in.
Literally.
****Play ambient sounds:*
https://mynoise.net/NoiseMachines/senegalUrbanLifeAmbienceGenerator.php *****
As you look around you see streets and buildings made out of concrete, covered by all sorts of plants.
Or rather ***Biological Machines****, also known as BM's.*
A mixture of plants, digital material, and electronics working together with originally either of three distinct purposes:
1. Evoking care for the natural world
2. Make people aware of their intertwined connection with nature
3. Facilitate meaningful and useful ways of coexisting with the plants around us
Nowadays BM's come in all shapes and sizes.
Providing people with all sorts of niche interactions, helping them to go about their business, providing scientists with demographic and climate data, and people and animals with free foods.
As you set about your reminiscing day, it feels like you see this world for the first time.
You interact with the BM's you've long considered mundane with a new sense of wonder…"

In front of you, you have a BM that has piqued your interest this day. You try to remember when it was first introduced, has it been around for long or not, what it does and how it works. As you think about these things you remember an article on an online tabloid about the introduction of this specific BM and why it's a game-changer.

Your task today is to write what you remember of this tabloid on the paper in front of you together with your group mates.

To get you started I have a list of properties living plants possess here.
and I would like you to choose one of the three cards marked with icons in front of you and pay special attention to the three questions that are listed on this card.

APPENDIX E: (Preliminary) Idea Collection & Synthesis



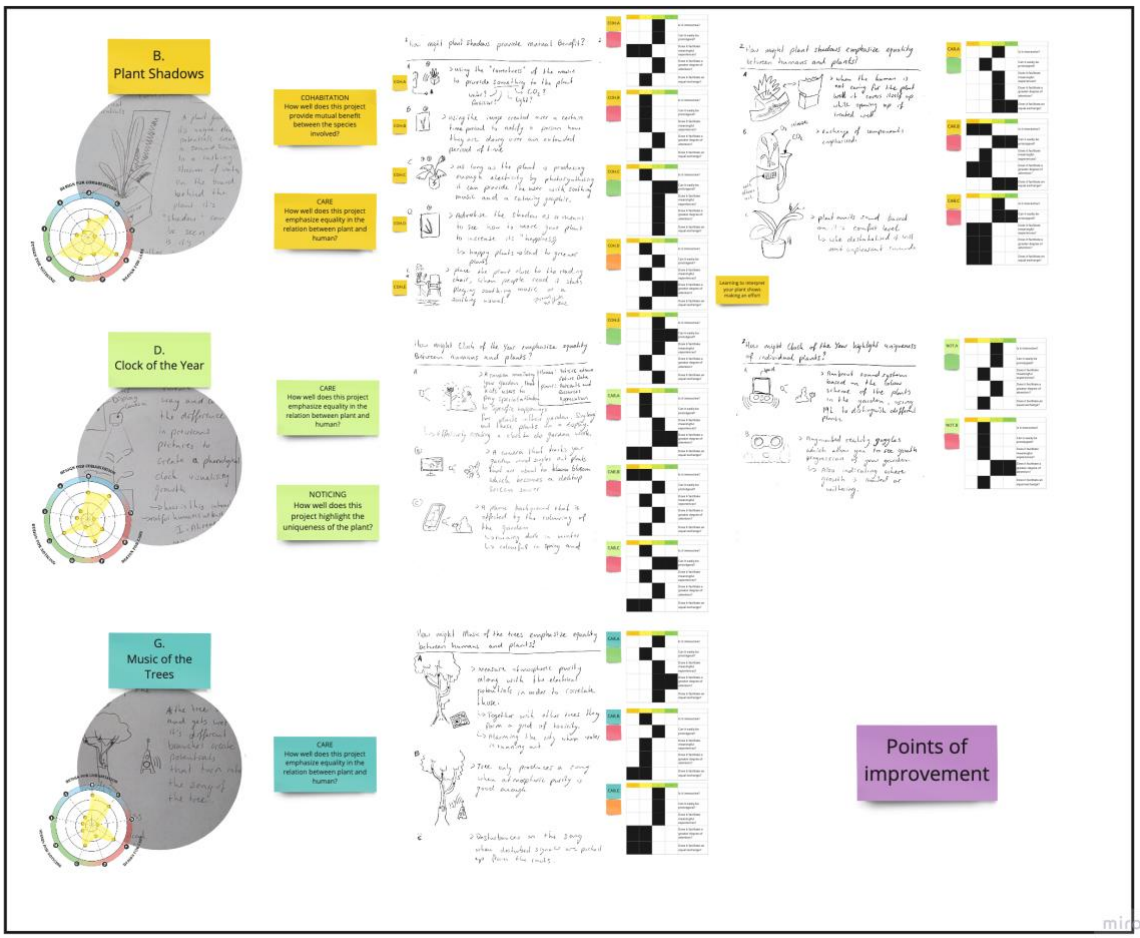
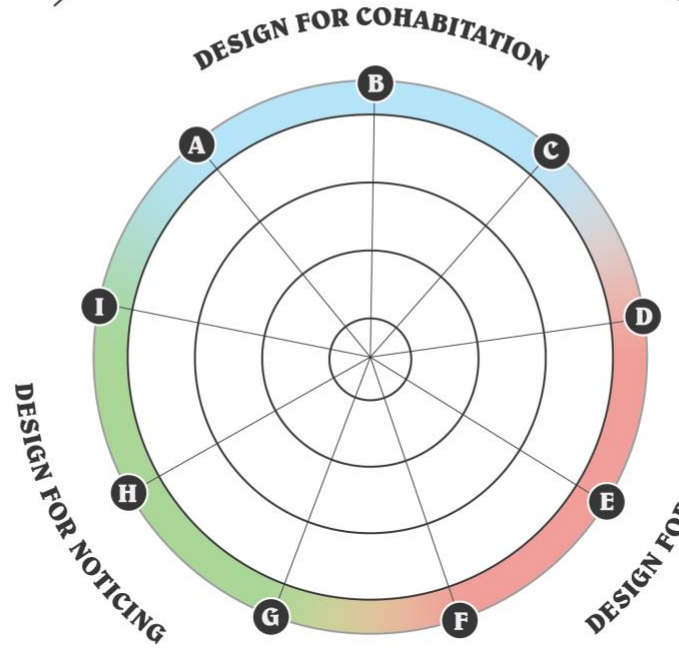


Figure 57: Iteration on first theoretically grounded ideas assessed with a Harris profile

APPENDIX F: Design for Plants evaluation tool: Amoebae Wheel

PLANT DESIGN EVALUATION
AMOEBAE WHEEL



COHABITATION

A. How well does this project provide mutual benefit between the species involved?

B. How well does this project preserve coexistence between the species within the habitat?

C. How well does this project decenter the human in the interaction

CARE

D. How well does this project emphasize equality between plant and human?

E. How well does this project emphasize the aliveness of the plant?

F. How well does this project facilitate attentiveness towards the plant?

NOTICING

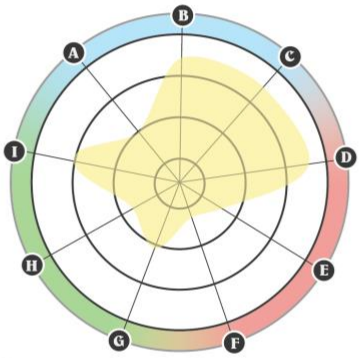
G. How well does this project highlight the uniqueness of the plant?

H. How well does this project highlight spacial & temporal differences exhibited by the plant?

I. How well does this project contribute to gaining knowledge of this plant?

PLANT DESIGN EVALUATION AMOEBE WHEEL GUIDE

This design model is meant for assessing more-than-human design projects that are situated in interaction between humans and other species. The model utilizes three design fields within more-than-human design which are aimed at tackling socio-technical issues. Design for Cohabitation is about mutual benefit, coexistence and decentering the human in habitation design. Design for Care is about equality in interaction, acknowledging aliveness and practicing attentiveness. Design for Noticing is about emphasising uniqueness and individuality, emphasising the changes over time that are produced by species and gaining knowledge.
In the figure below an example is given for a filled in version of the framework. This specific example project has a strong tendency to maintain current relations between species and supporting existing ecological infrastructures. Therefore, it scores well in emphasising equality, decentering the human and preserverance.



A. This question is not so much about survival as it bescribes benefits that might be contributed to some for of symbiosis

B. This question is about maintaining more than human existence without a necesity for interaction and/or benefit apart from staying alive

C. This question is about valuing more than human desires in the design and placing the human on the same level as other organisms involved

D. This question is about communicating the equality between humans and other species in their involvement within the biosphere

E. This question is about communicating the signatures that make the other species to be considered alive.

F. This question is about the extent to which the project facilitates spending meaningful time with the specific other species that is involved

G. This question is about communicating the uniqueness of this species compared to other species.

H. This question is about communicating the species capability to change both space and time, by means of movement, color change, sound, physical appearance.

I. This question is about informing the user on the specifics of this species or individual.