Final Documentation

Redesigning beekeeping practices
in the digital era

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BeeMo

A human centred redesign challenge inspired by the Meta HiLight technology

Aalto University

LINKÖPING UNIVERSITY

SUGAR

ATTRACT

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Executive summary

Beekeeping is as old as time...

Beekeeping is a practice as old as time, however today beekeepers worldwide are struggling to keep their bees alive, due to drastic climate change that leaves the beekeepers to fight the battle against the spread of pests and unpredictable seasons. One of these pests is Varroa mites, that climb on the bee and once it enters the beehive it infects the larvae with viruses and weakens the entire colony. Climate fluctuations cause bees to become disoriented that leads to mass colony deaths as the bees leave the hive too early in the Spring to survive it. Beekeepers are struggling and old practices such as applying heavy amounts of pesticides into the hive are no longer efficient ways.

Our team, consisting of students from Aalto University and Linköping University was given the challenge of redesigning beekeeping for the modern era with an upcoming technology Meta-HiLight by our corporate partner ATTRACT. By combining the conservative industry of beekeeping with an innovative technology, our team started to imagine how beekeeping practices could be developed for a more resilient industry. All started with extensive research and user interviews that opened the challenges of modern beekeeping to the team and led to phase of exploration with many different prototyping phases from dark-horse to functional ideations. That eventually lead to the final solution.

The solution, BeeMo is an open-source initiative that aims to distribute innovative beekeeping solutions as widely as possible, while fostering improved living conditions for bees and enhancing safety measures for beekeepers. The device is inserted to the entrance of the beehive, where bees are easiest to access. The device is modular consisting of three parts: a varroa mite treatment module, tunnel entrance and a sensor module. The modularity allows beekeepers to modify it to their needs and leaves room for future innovations such as Meta HiLight.

1.

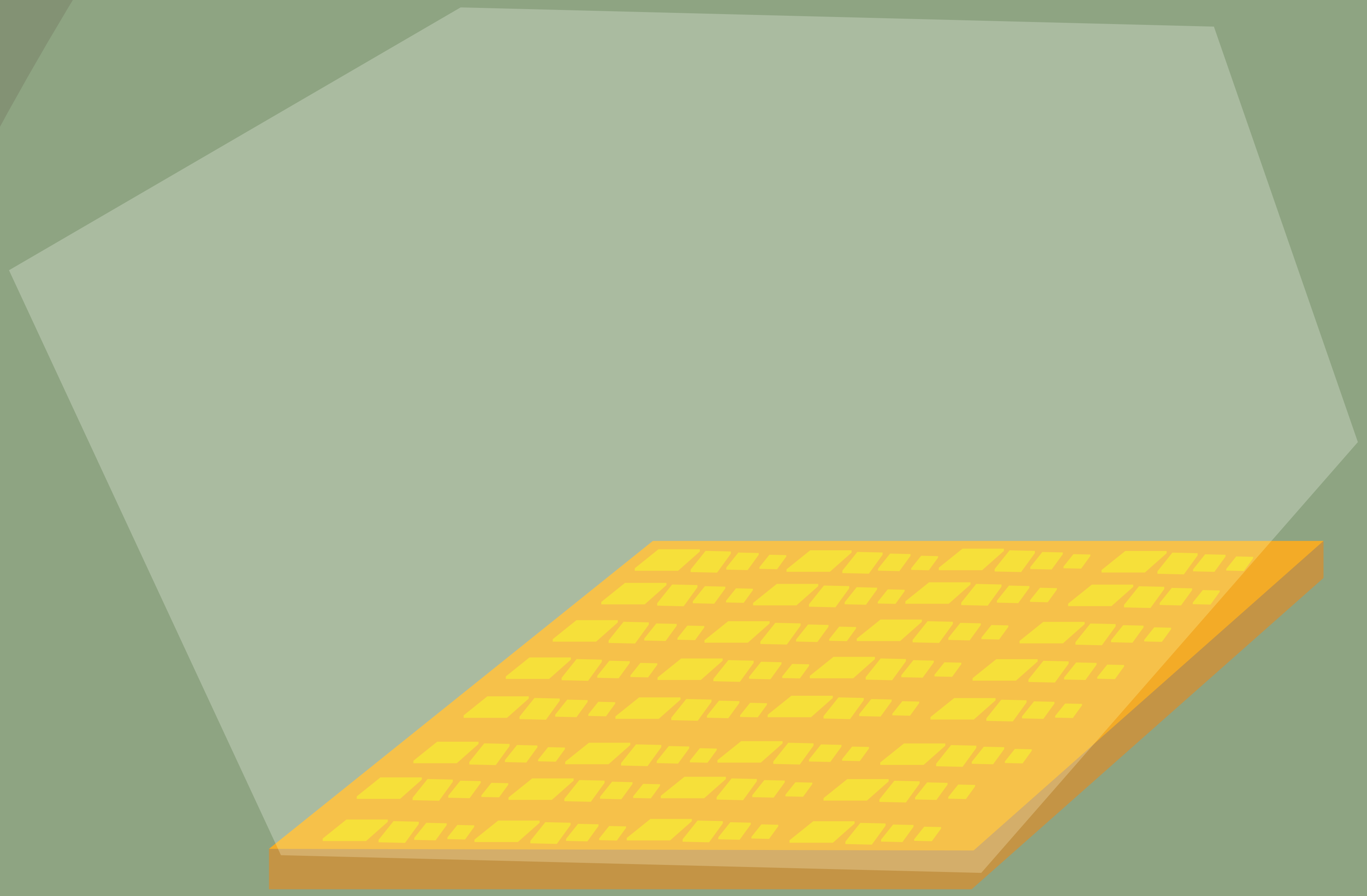
The setup

Corporate partner

ATTRACT is a European consortium formed by six scientific laboratories from the field of optics funded by the EU. Their main objective is to turn scientific breakthroughs within the field of detection, imaging and computational technologies into commercialized services and products. To enable this ATTRACT cooperates with experts in the business and entrepreneurship field.

The technology provided to our team is the so called “Meta-HiLight” by “3D-META”. This technology makes use of nano structures placed over a piezoelectric material to change properties of the incident light, such as its polarization state or reflection angle. The aim of this technology is to reduce the costs, complexity and size of similar components currently available in the market.

The laboratory based in Oslo, Norway, is the homebase from the technology perspective. Our primary contact person for the technological-related topics is Paul Thrane, from SINTEF Smart Sensors and Microsystems.



Meet the team:

Our team consists of students from Linköping University and Aalto University. Our members bring together business, engineering, arts and education expertise, making interdisciplinarity a great asset.

Jaana Talja

Business

Juan Gil Escribano

Mechanical Engineer

Reti Kilvet

Designer

Laura Putkinen

Business, Education

SCHOOL: AALTO UNIVERSITY

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Fabian Andersson

Business strategist

Lovisa Sajland

Business strategist

Märta Sund

Biomedical Engineer

SCHOOL: LINKÖPING UNIVERSITY

LiU LINKÖPING UNIVERSITY

Methodology

Our team addressed the challenge given in this project through a design thinking methodology. This approach allowed us to systematically tackle complex a real-world problem with creativity and innovative proposals while placing the user at the center design. Design thinking involves a non-linear iterative process in which user pains are understood and defined, research is conducted and assumptions are challenged, ideas are generated and quickly prototyped and tested, user feedback is collected and the original problem statement redefined based on the outcomes.

On top of that, we followed a time line structure given by the human-centered design thinking network SUGAR. This time line consists of multiple successive micro design thinking cycles over a time scale of 9 months. Each of those cycles has a particular goal or approach in mind. In this way, we had time to explore both down to earth and radical ideas to get as wide knowledge and user feedback as possible.

2.

The journey

The nine-month project has taken the team on a long journey with its twists and turns. The project started with understanding the challenge, the given technology as well as beekeeping itself. Requiring plenty of research and user interviews that resulted in understanding the stakeholders, user journey and personas that left the insight that most beekeepers are struggling with Varroa Mites in their beehives. Prototyping left the room to explore different areas of beekeeping, even dystopian beekeeping practices. Funky prototyping led us towards the final solution that then was developed further in the later months into a real functioning product.

2.1 Key learnings

During the fall stage of the project we dived into the basics of beekeeping: bees' colonies and lifecycle, types of beehives, and their pollination role. Other relevant trends and topics were also researched: digital beehives, pests, and alleviation of poverty through beekeeping. Beyond desktop research, we conducted interviews with both professional and hobbyist beekeepers of multiple ages, and researchers related to the field. All these learnings set the basis for the development of our project.

In this segment we list the key learnings our team gathered during the project.

To start with, we learnt that bees are difficult to control. Their behaviour is complex and sometimes unpredictable. The wellbeing of the whole colony starts in the beehive. A correct beehive design should ensure correct ventilation, insulation, space, and protection for the bees. Neglecting these aspects will lead the colony to swarm, decrease in size or even die.

Outside the beehive the main concerns for the bees are food availability, weather, harmful chemicals, and pests. The beekeeper can effectively act on many of the above-mentioned issues. However, other factors, like climate fluctuations, external chemicals and infestations, cannot be controlled by the beekeeper.

From the beekeeper's perspective the main identified concerns about their colonies were pests and winter season survival. Pests are a worldwide concern. Among all of them, American foulbrood was identified as number one, closely followed by Varroosis. Pests are present all year along, but winter season is specially important since bees do not leave the beehive and pests spread easier then. Treating the colony before winter is a common practice to either treat or prevent diseases and pests.

There are more reasons that explain colony losses during winter, such as the loss of the queen, excess or lack of food, natural death of bees, condensation inside the beehive, a weak colony, or attacks from other animals. Nevertheless, due to climate change, the end of winter has become a threat as well, since bees leave the beehive during brief warm periods and get killed by sudden temperature drops. Moreover, these warm periods disrupt plants blooming cycles, making them bloom outside the natural season and killing the flowers once the temperature suddenly drops.

Lastly, it’s important to note that beekeeping as a practice requires heavy lifting of the boxes and frames when filled with honey. Moreover, beekeepers are always at risk of getting stung when interacting with the hives.

The mentioned learnings become crucial in our design process, as they set limitations and requirements for our work.

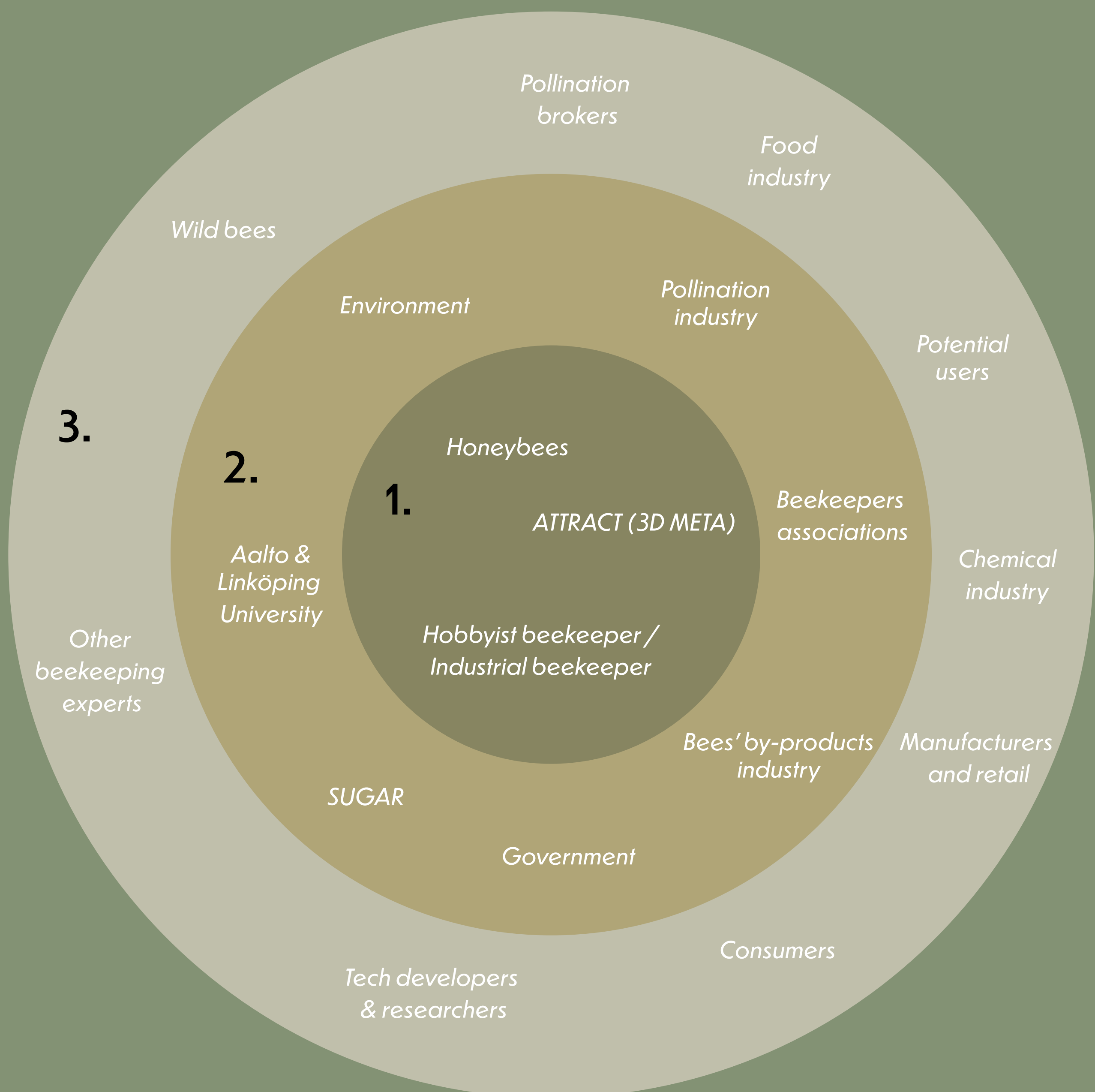
2.2 Stakeholders

The stakeholder map offers a quick overview of the main identified parties related to beekeeping. An updated version of the stakeholder's map is shown here.

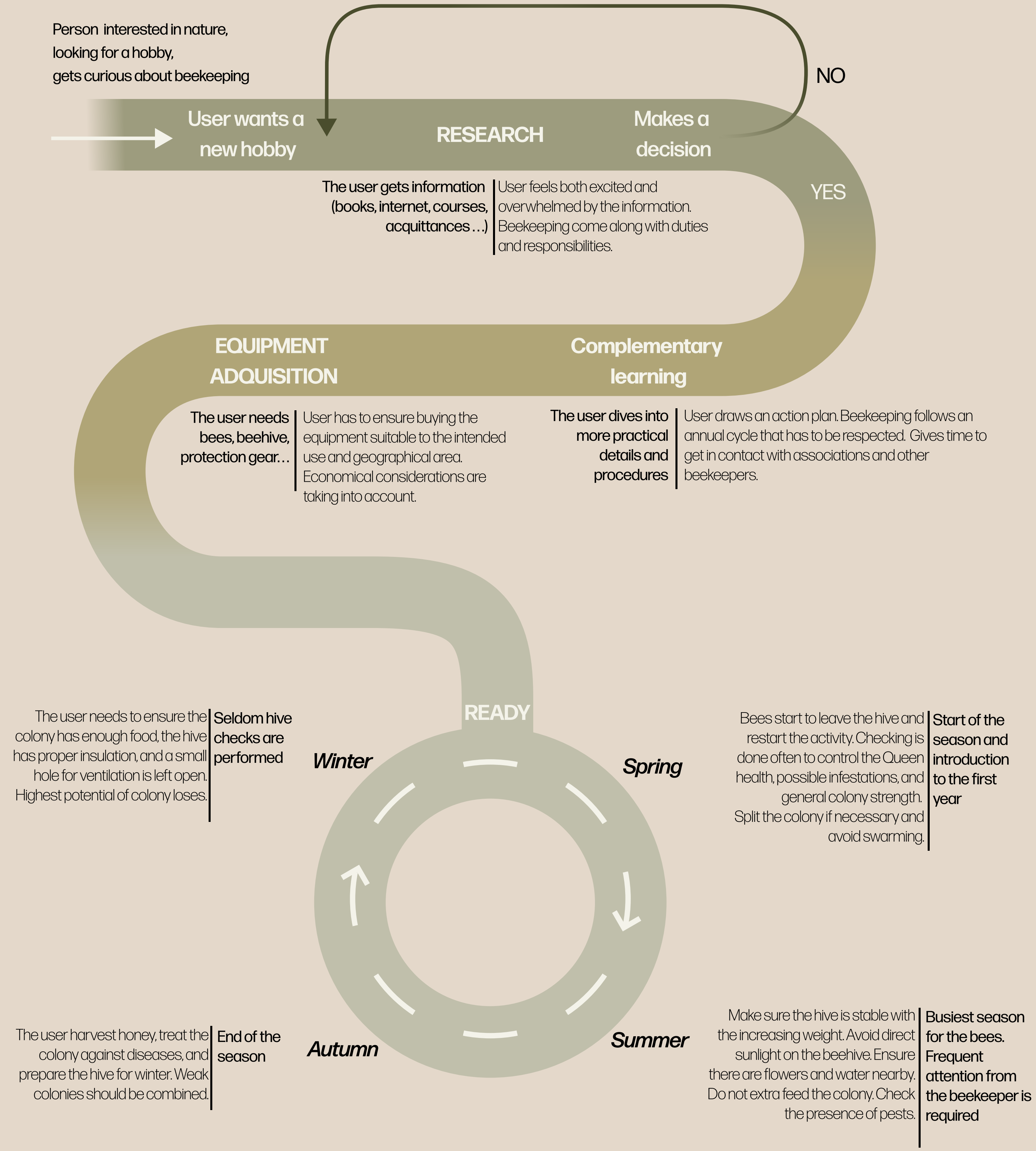
1. Core stakeholders participate actively on the project as main subjects.

2. Primary stakeholders relate to the core stakeholders by being essential to them, or by making use of them.

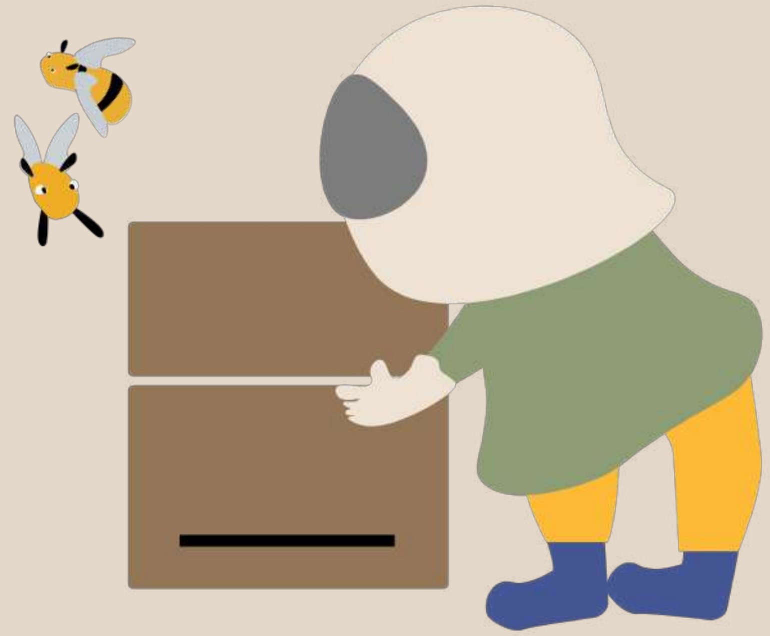
3. Secondary stakeholders are also players on the beekeeping field but with further connection with the core stakeholders. They can take part on beekeeping trough intermediate actors or trigger changes on the field.



2.3 User journey (hobbyist)



2.4 Personas



Hobbyist

A hobbyist beekeeper is ***someone who does beekeeping for fun in their free time,*** not expecting major profits. The majority of hobbyist beekeepers are of older age. They usually practice beekeeping because of the urge to stay in touch with nature and are willing to do a lot of things by themselves without using technology.

The hobbyist's ***main need is to keep their bees alive.*** Bees are like pets to them and there seems to be a connection between the beehive and the beekeeper. Getting honey from beekeeping, even if it is not a big amount, is like a reward for them.

Hobbyist beekeepers are extremely conservative and have ***usually learned the skills from an older and more experienced beekeeper***. It is widely believed that there is no need, or possibility, of changing the way of doing things since they have been effective for generations of beekeepers before them. Moreover, hobbyist beekeepers don't usually have a lot of beehives and it is too risky for them to test something new and lose the bees they have.

Familiar and simple equipment is important to them. They do not usually test a lot of new solutions. However, if the product is affordable and easy to access, they are willing to give something new a try.

Industrial beekeeper

The needs of industrial beekeepers are mainly the same as the hobbyists, but there are some details worth mentioning.

Industrial beekeepers do beekeeping because of honey and to earn a profit when selling it. Time efficiency is one thing that industrial beekeepers care more about than hobbyists. Hobbyists are quite often retired people who enjoy the process of beekeeping and have more time to do it. That's why time efficiency is not the main problem for them. Industrial beekeepers, on the contrary, have ***a lot of beehives*** and the process should be ***as quick and time efficient as possible.***

To add, industrial beekeepers want to have the maximum amount of honey and profit. The bees should be healthy and safe in order to do that. They also need to have it ***cost-efficient for scale-up usage***. Industrial beekeepers have a lot of beehives and if the product or the solution is expensive, they won't be able to use it in every beehive. Otherwise, they would end up spending more money than they earn.

Learnings

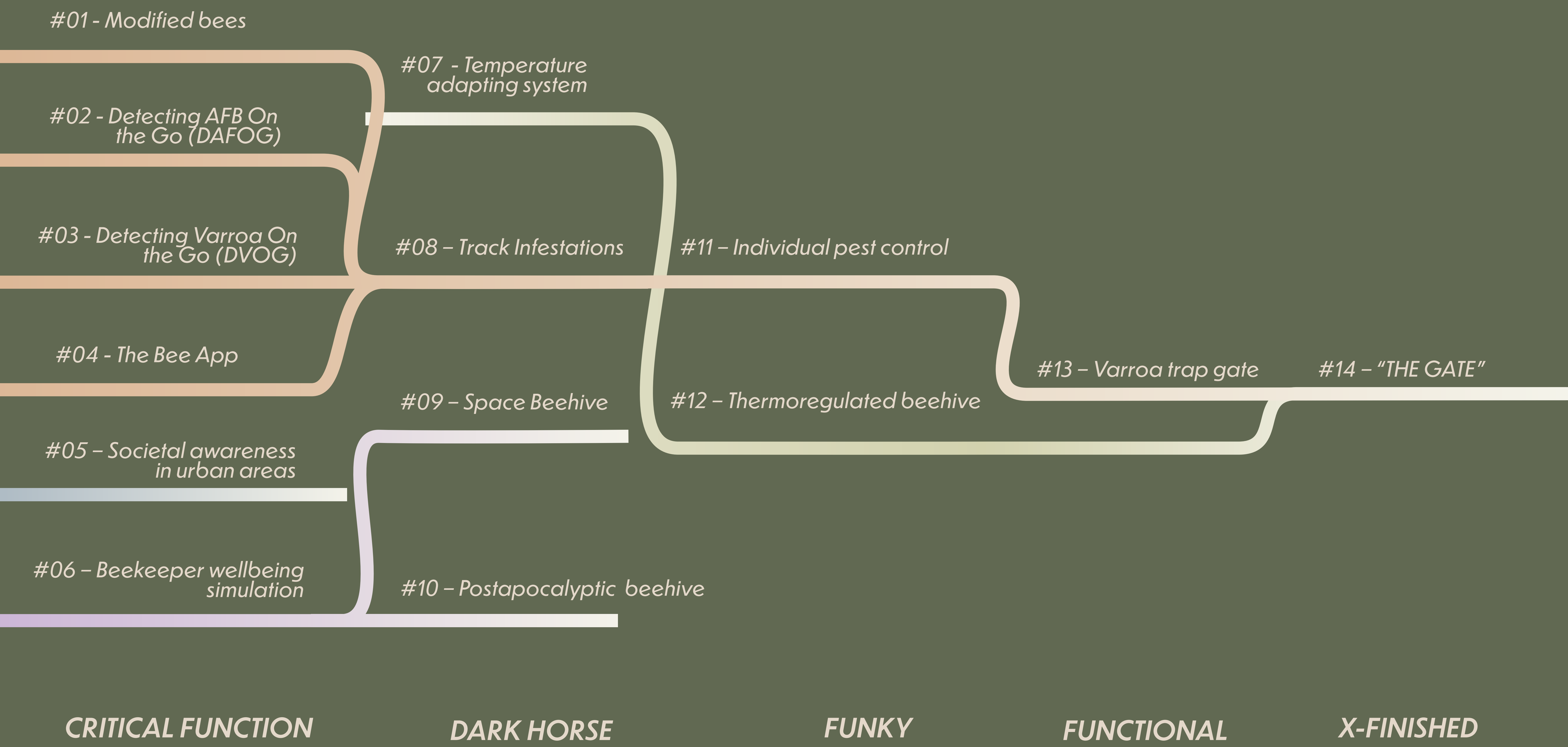
Our solution or product should be safe for the bees and in line with their living standards. We should not interfere too much with nature. Beekeepers have a moral attachment to the bees and won't use something that they think is bad for the bees. They want to have a maximum performance from their bees naturally. A beehive is an investment that they cherish and are not willing to damage. Furthermore, the bees should not become so annoyed that they end up stinging the beekeeper more because of our solution. Although the beekeeper usually interacts with the beehive in safety equipment it is still possible to get stung.

In addition, if we make something that confuses the bees too much, they may swarm and the beekeeper will be left with no bees. Bees can be trained and they are good at adapting, but still the solution should not make them so uncomfortable that they decide that it is easier to leave.

Moreover, the safety equipment that the beekeepers wear makes interaction with the beehive more complicated and that is one more reason to have as simple a solution as possible. There is no reward for using more complicated and difficult equipment, at least nothing has been proven yet. As many care about nature, the reusability of the product and adaptivity is an essential factor. Buying one solution that can be adapted to multiple different beehives is also cost-efficient. Reusability supports the traditions that are within beekeeping. The material the product is made of is also important. For example, beekeepers prefer and trust wood over plastic.

2.5 Prototypes

To create a comprehensive understanding of our final solution, the X-Finished, we aim in this section to present all the other prototypes that have guided us towards our final solution. Hence, the purpose is to showcase the problem spaces we have pinpointed rather than describing each protype in detail. Therefore, more thorough descriptions of each prototype can be found in the appendix.



CRITICAL FUNCTION

Early in the process of our project, we aimed to explore the field of beekeeping in order to understand the practices and also to grasp where the beekeeping industry was in need of attention. Our key insights from the project's first phase were to shed light on infestations, beekeeping as a practice, and the importance of beekeeping. The idea was to also live out the process of beekeepers, to fully understand how they operate and why they would need attention in regards of further development.

Infestations such as American Foulbrood and Varroa Mites have been highlighted as major issues when it comes to beekeeping. The absence of tools to manage the treatment or to prevent the spread of these infestations aggravates beekeeping today. Furthermore, the beekeeping industry has not been subject to drastic development or changes, leading to the practices falling short of expectations. Therefore, initially, we came up with four prototypes to tackle the challenge of an underdeveloped beekeeping industry.

#01

Modified bees

With the help of genetically Modified Bees, we would eliminate the issue of bees being harmed by infestations due to the bees protecting themselves from such intrusion.

#02

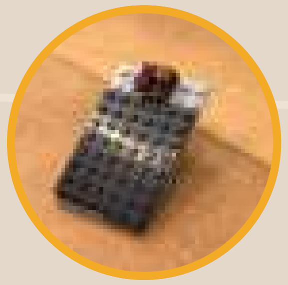
Detecting American Foulbrood

Through a device that utilizes sensor technology it would be possible to take samples of tissue at the entrance of the beehive giving feedback of if the beehive is infested by American Foulbrood or not.

#03

Detecting Varroa Mites

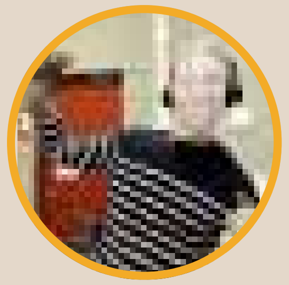
Through a device that utilizes sensor technology it would be possible to take samples of tissue at the entrance of the beehive, hence also quickly get feedback if the beehive is infested by Varroa Mites or not.



#04

The Bee App

An app aiming to detect the level of Varroa Mites inside the beehive. By scanning the frames, the app can identify the level of Varroa Mites through algorithms.



#05

Beekeeper Wellbeing Simulation

We built a simulation of working on a beehive to understand how beekeeping is executed. We wore big gloves, covered our face with fabric and tried to open a box and check the frames inside. This allowed our team to empathise with beekeepers and understand some of their struggles.

#06

Awareness in Urban Areas

The concept of this prototype was to assume that an average person does not know about bees and their activities. Therefore, we designed an urban space where we could share live data from beehives to the by-passers. The aim of this prototype was to create awareness towards inter-species' life in urban spaces.

DARK HORSE

In comparison to the initial part of the project, the Dark Horse Prototypes aimed towards reflecting our ‘out of the box’ creativity. At this time, we understood that to respond to the project’s initial challenge, we would have to take drastic measures to improve the beekeeping practice. Today, the beekeeping industry is slow moving in terms of its development, hence the Dark Horse Prototypes aimed towards responding to realistic problems, but through what could appear as unrealistic solutions.

Additionally, the research done for the Critical Function Prototypes led us to the conclusion that climate change had a drastic impact on bees and the beekeeping industry, which was also the main reason for pursuing Temperature Adapting System and Track Infestations. Moreover, we also realized that wicked problems might have required wicked solutions, hence we exaggerated some of our solutions, the Space Beehive and Postapocalyptic Beehive.

#07

Temperature adapting system

As we dived deeper into the issue of infestations, we encountered the problem of climate fluctuations. Unpredictable changes in climate confuse the bees’ understanding of seasons. Therefore, we developed a Temperature Adapting System to control climate fluctuations.

#08

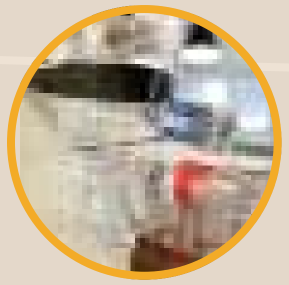
Track infestations

The process of estimating the amount of Varroa Mites in a beehive is very manual and out-dated. Thus, the idea of placing a sensor in the beehive’s entrance arose. When the sensor identifies a Varroa Mite, it sends out soundwaves which scares the Varroa Mites away.

#09

Space beehive

We wanted to find alternative approaches to beekeeping from traditional ways, and create new avenues for beekeeping as an industry. This exploration phase led to prototyping a beehive in space. The aim was to simulate the same thing as happens on earth, but in space. The prototype was, therefore, placed in a space garden where the bees would work as pollinators.



#10

Post-apocalyptic beehive

The post-apocalyptic beehive explores the minimum possible living conditions of bees and simplifies the beekeeping practice to a non-expert level. The aim of the exploration was to push the boundaries of beekeeping and understand the core essence of the practice. The prototype consists of plastic bottles that form a nest-shaped hive for bees. The design can be built by anyone and it can be used for all steps of beekeeping: capturing a colony, accommodating the colony and harvesting honey.

FUNKY PROTOTYPES

The Funky Prototypes aims towards highlighting what was this far known in the project and to stretch the boundaries without becoming too unrealistic in regard to the solutions. The prototypes were neither aimed towards being complete designs, instead, we wanted them to successfully prove the concepts so that we could make a decision if it should be further pursued or not.

#11

Individual Pest Control

The beekeepers we interviewed expressed concerns regarding the non-environmentally friendly pesticides that they use in the fall to treat the beehive from Varroa Mites. These pesticides harm the bees and can only be used after the honey has been harvested. Therefore, we developed a system attached to the beehive's entrance enabling solely treating the bees infected by a Varroa Mite before entering the beehive. The prototype also allows for treatment of bees and beehives during longer periods of time, even when the honey is not yet harvested.

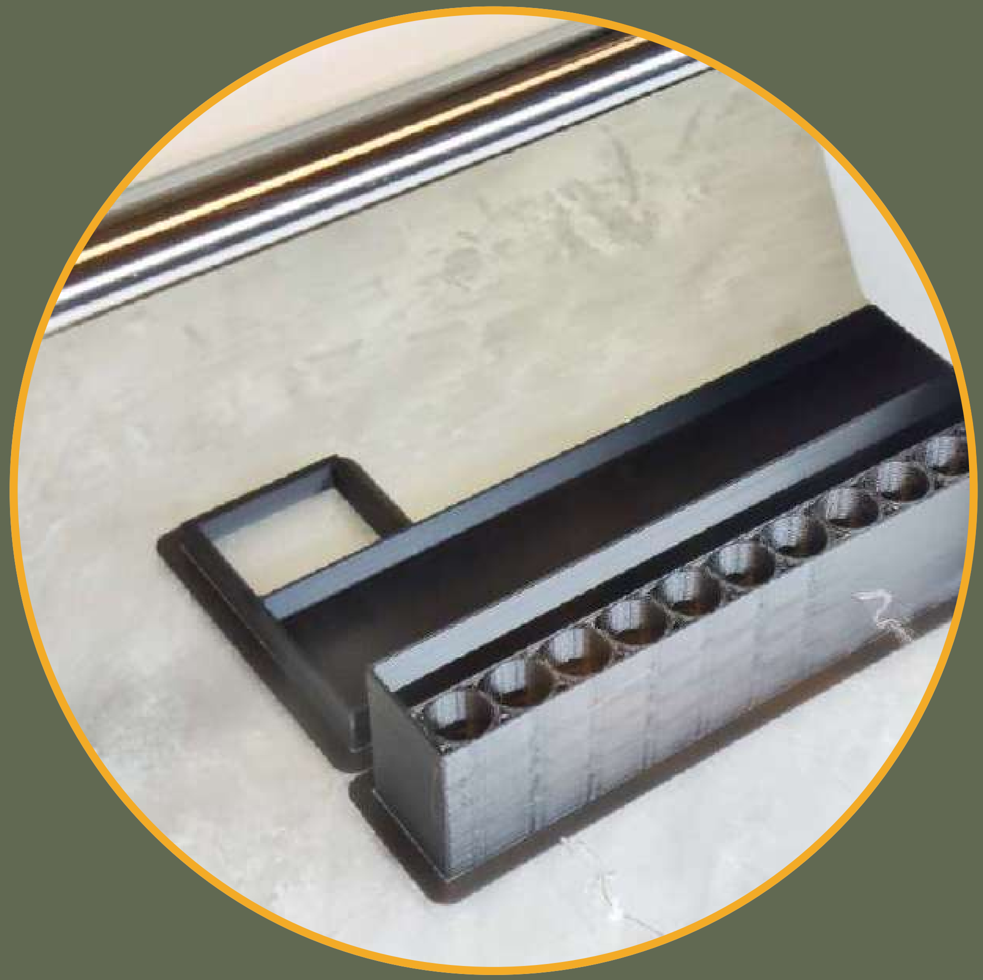
#12

Thermoregulated beehive

As a result of climate change's major impact on bees' living conditions, we decided to explore this matter more thoroughly. Aside from prototype 7, which also focused on temperature fluctuations, this prototype had a different variant of temperature regulating system.

FUNCTIONAL PROTOTYPE

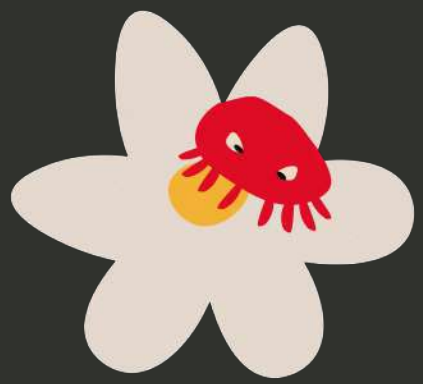
The Functional Prototype was, compared to the Funky Prototype, aimed towards highlighting the most crucial need of the beekeeper that we found, and to respond to that need with a reasonable solution that would be possible to integrate within the beekeeping practices of today.



#13

Varroa trap gate

To minimize bees' exposure to pesticides is crucial to enhance their living conditions. The gate is attached to a beehive's entrance and has a tray placed under the tunnel system with the 2-hydroxyhexanoic acid (CAS number: 6064-63-7). This specific chemical disperses a certain smell which attracts Varroa Mites to automatically jump of the bees. Hence, the Varroa Trap Gate discards bees' exposure to pesticides completely.



3.

The solution

Through the prototypes shown before we explored the limits of reality in terms of practicality, resources allocation and usability.

The funky prototype already showcased the final aim of our team and proved the value of our idea: to treat varroa mites in a more effective way while reducing the amount of pesticide used and labor. However, it was evident that it was a costly approach that not many people were willing to use. Taking these learnings into account and basing ourselves on research about Varroa mites' behavior we developed our final solution.

3.1 Final prototype

The final solution is a modular system that is placed at the entrance of the beehive. The system is composed of three parts: the tunnels module, the chemical drawer, and the tech module. All together the system allows the beekeeper to protect the beehive against varroa mites thanks to a chemical found on the chemical drawer, and to optionally apply digital solutions for tasks such as monitoring or thermally regulate the beehive, if desired.

The tunnel system

The tunnel module is the base structure of the whole system. The tunnel system contains the holes that allow the bees going in and out. At the same time defines the outer dimensions that the physical entrance of the beehive can have. It is a structural component and is meant to be rigid enough as to avoid deformations and allow the smooth extraction of the chemical drawer when needed.

The dimensions of the gate were based on market research of Langstroth beehives currently sold. The height of the entrance was measured at 2cm, with a common maximum length of 40 cm. The gate system therefore was designed to be 1.9 cm tall to allow some expansion of the wooden frame and other irregularities.

The tunnels present a circular shape that slightly widens towards the bottom. This shape was designed after a field experiment during spring season in which was observed that the big pollen sacs in the bees' legs were too big to fit through the tunnels. The custom shape gives extra room for the bees to comfortably walk through the tunnel when carrying great amounts of pollen. The original design made use of 7mm holes to restrict the access of other animals such as field mice. However, this size was too small for the bees even when not carrying pollen. The final base size was increased to 8.4mm. It is worth mentioning that most beekeepers leave a rectangular entrance to their beehives bigger than 8.4mm in height and width whole year around. Therefore, our tunnel system actually behaves as a first barrier against other animals unlike an entrance without any tunnel system.

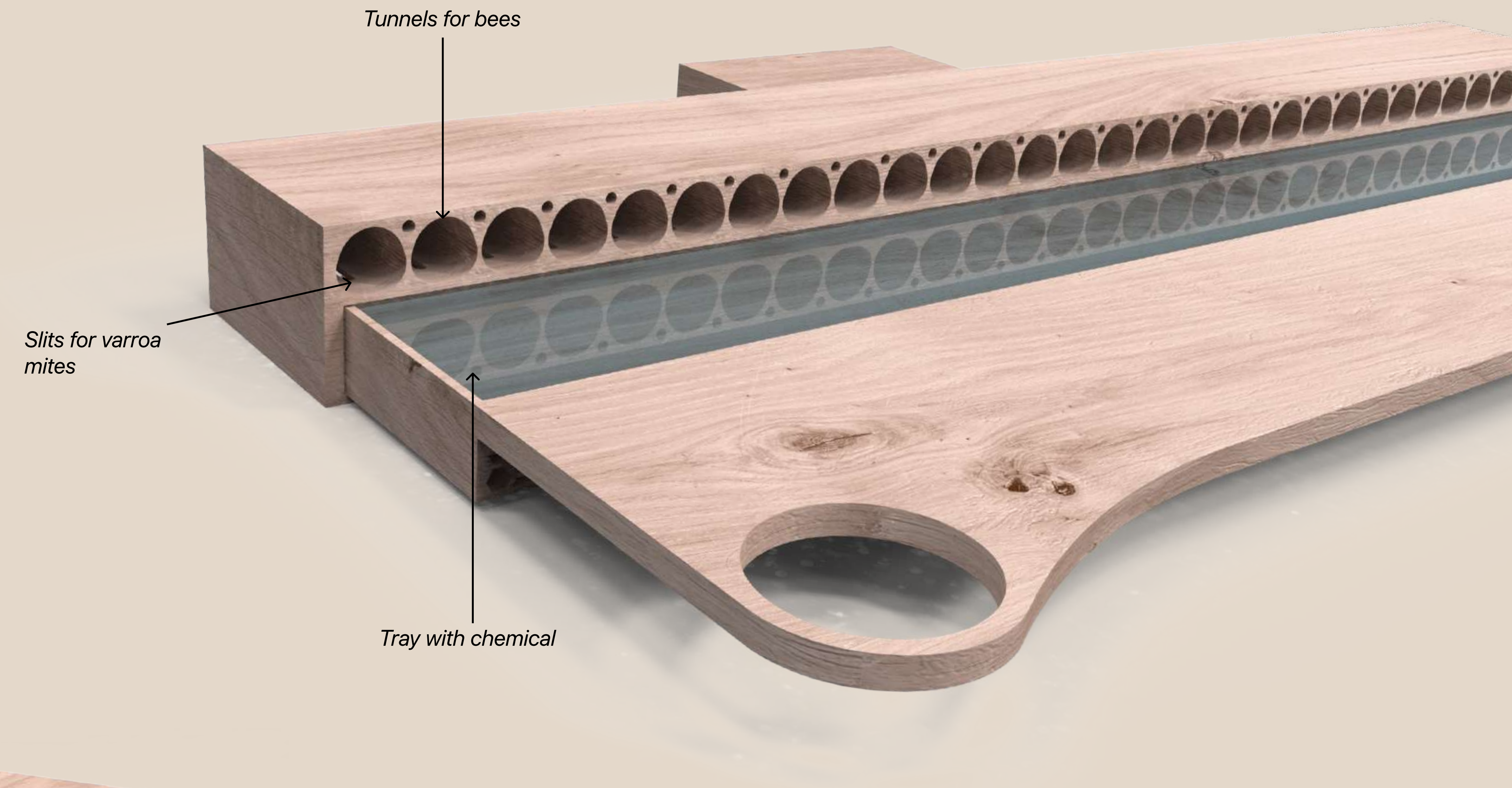
Since the gate is placed at the entrance of the beehive, the entrance area is reduced, thus reducing the air flow and ventilation. To counter this issue, all the components were made as slim and narrow as possible to increase the frontal area dedicated to ventilation. Extra holes and grids were added between the tunnels and to both sides of the tech module, under the chemical tray. Nevertheless, even during summer, none of the beekeepers we interviewed had a fully open entrance to the beehive. Results that the area they kept open during summer is equal to the frontal area of a gate fully open with our system installed in it.

Finally, the tunnel system, and the chemical drawer, is provided in three different lengths: 10cm, 28cm, 38cm. This is so that beekeepers can exchange the gates to adjust the total opening of the beehive according to the season. The smaller gate is meant to be use in winter, while the biggest one is meant for summer periods.

The chemical drawer

The chemical drawer is a slim sallow tray that allows to deposit a thin layer of the desired chemical under the tunnel system. The design is so that the chemical is placed less than 1cm away from the bottom of the upper tunnel to increase the chances of the mites to get trigger by its smell.

The drawer also serves as holder for the tech module. The tech module slides in the slots under the tray and is fixed thanks to a quick release system. It is designed so that the chemical drawer and tech module can be removed from the gate without having to extract the tunnel module nor opening the hive.



The tech module

The tech module is a narrow and low box with a removable lid, that fits into the middle of the modular system, facing the inside of the hive. It is volume dedicated for tech solutions, of any kind. A sensor module is proposed as showcase of its utility. Thermal regulation or dispense of treatments inside the hive are some of the alternative uses foreseen during the development of the project.

The tech module was made narrow to favor the ventilation of the hive. Its height is limited by the height of the chemical drawer so that it can be removed without having to remove the tunnel system from the hive. On the other hand, its depth is flexible, and can be as long as needed.

3.2 Working principle

Modularity

The term modular in this system means that it is possible to add or change the functionalities of the gate.

The chemical drawer was designed to admit chemicals in different forms, such as a gel solution, or sticky band. Also, it is not constrained to a single chemical and opens the door for other substances in the future. Other companies can design their own solutions and add features. As an example, when using a chemical releasing sticker, it can be made of such material that changes its color over time or temperature. In this way the beekeeper has a visual aid to know if the chemical has lasted less than expected due to excessive heat. These features can be patented and offer companies business opportunities.

The tech module offers the greatest flexibility. Each manufacturer could design a module based on their own ideas. The only requirement is to have a connection system of the given dimensions and size to connect it to the gate.

Varroa mites

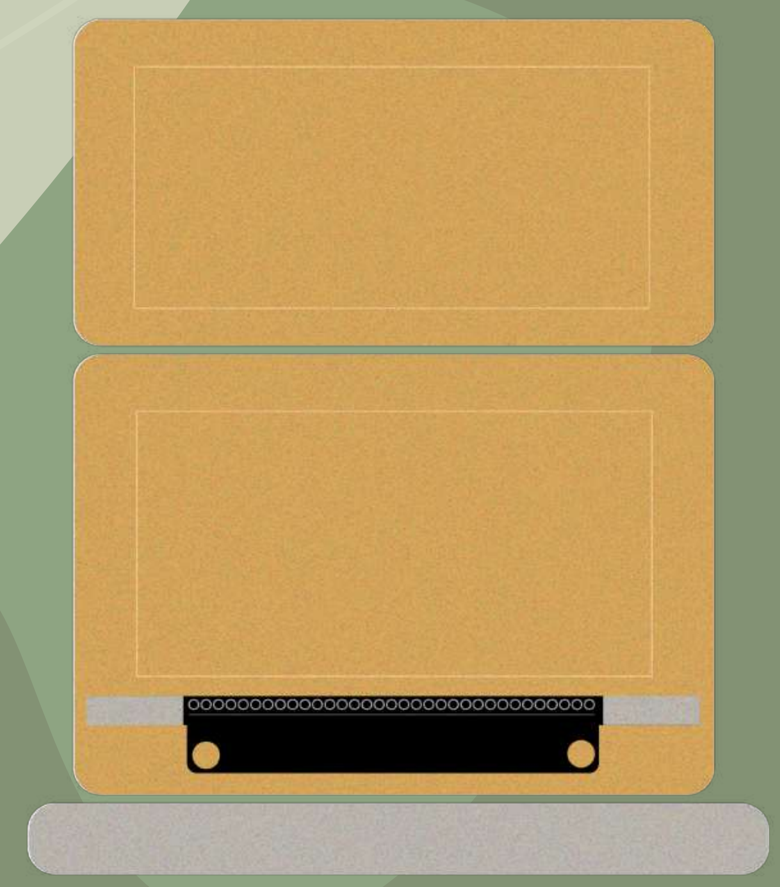
Current solutions fighting varroa mites reduce the mites' population in the beehive by killing as many individuals as possible. This can be achieved through a variety of techniques. The most common procedure is the application of pesticides inside the hive's boxes or into the frames, which introduces toxic elements in the honey, wax and frames in general. More natural pesticides have been developed in recent years, such Thymol, which are better tolerated and safe for bees. However, they do not completely eliminate the abovementioned risks. More recently, thermal treatments have been also proposed as an effective pesticide-free alternative, with the drawback of requiring costly equipment, the sacrifice of some brood, and tight treatment schedules.

Most novel proposals include the use of ultrasounds to kill and disturb the varroa population inside the beehive, although its effectiveness requires further research to be validated.

Our proposal swifts the working principle from killing varroa to trapping varroa. In this way, harmful pesticides are ditched, costly equipment is not required, and is not linked to tight frame windows.

We were inspired by the research work done by Mark J. Carroll [1] on Varroa mites' behavior within the beehive. Said research aimed to understand how varroa mites orientate themselves inside the beehive and how they are able to find the brood in which to hide and reproduce. The study found that the mites react to the smell of specific substances that are produced by the bees when preparing brood cells to laid new eggs. Further research [2][3] isolated each of the chemicals in those substances and identified two main chemicals that triggered mites, being 2-hydroxyhexanoic acid (CAS number: 6064-63-7) the main one. Said chemicals seemed to be more effective when placed less than 1cm away from the mites.

This research set the stage for our solution. We first took the already existing concept of a tunnel system for the entrance of the beehive and added small channels on the bottom of each tunnel. These channels, sized according to the mite's body, communicate with a tray underneath that is filled with the desired chemical. The chemical evaporates slowly saturating the air within the tunnel. When the bees go through the tunnel, they slow down, and give time for the mite to react to the chemical, jump off the bee and crawl to the chemical tray moved by their natural instinct.



Tech module

The working principle of the tech module depends on the manufacturer of the module. The tech module can contain different solutions to tackle different problems. For example, the sensor module showcased in this project can monitor the health of the beehive through its multiple sensors. Temperature and humidity sensors help to determine if the colony is able to regulate the climate inside the beehive, which is also an indicative of a decreasing size colony. Temperature and humidity can be used as well to notify when the beehive has been opened or of sudden extreme weather. The microphone can detect swarming alarms and notify the beekeeper. The microphone can also detect if a colony is being attacked. A combination of sensors information can be contrasted with further colony analyses and detect macro patterns that happen throughout the year or the seasons.

Tunnel system

The tunnel system was designed following natural patterns that the bees create in nature to regulate the entrance of their beehives. Similar tunnel systems can be found in other commercial solutions available in the market. Both statements help to prove the feasibility of the system. Bees require little time to get adapted to the system and its implementation can be done steadily over time when implemented for the first time.

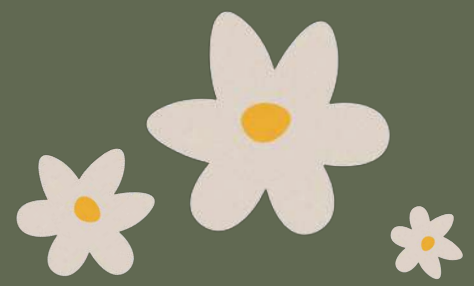
Thermal regulation module (future addition)

Another novel example could be the thermal regulation module, which proposes to cool down the entrance of the beehive through Peltier cooling pads to trick the bees to think that it is cold outside. This is done when the temperature outside is optimal for bee activity but a sudden storm is about to happen and bees cannot predict it. By cooling down the entrance time in advance bees will doubt about going outside.

To recap...

Through our final prototype we learned three things:

1. **Simple technological solutions** could help to increase productivity and develop solutions against climate change.
2. Beekeepers are, in general, not open to adopt technological solutions. However, **they would make an exception if the solution can solve their most urgent needs and are cost efficient.**
3. **Varroa mites infestation is the number one issue among beekeepers.**



The aim of our project was to redesign beekeeping for the digital era....

The aim of our project was to redesign beekeeping for the digital era, and this means to solve current problems and prevent future ones. With this mindset and validation from our research, we designed a solution that solves the current number one pain of beekeepers without using digital systems (tunnel system and chemical drawer) but which is ready to be used along technological solutions.

The beekeepers are mostly looking forward to our no-contact chemical treatment for varroa mites. However, if the beekeeper also wants to try digital solutions with a low threshold, the gateway system acts as a platform for experimenting with digital add-ons. No need to buy new systems, unknown hardware, or keep changing gates and digital solutions due to incompatibility.

Given that the gate aims to treat varroa mites, it is expected that many beekeepers will be willing to try. This means a great number of gates placed into beehives will be ready for future digital solutions. From a business perspective, third party digital solutions would have ready a solid customer base ready to install their products.

3.3 Business model

Financing

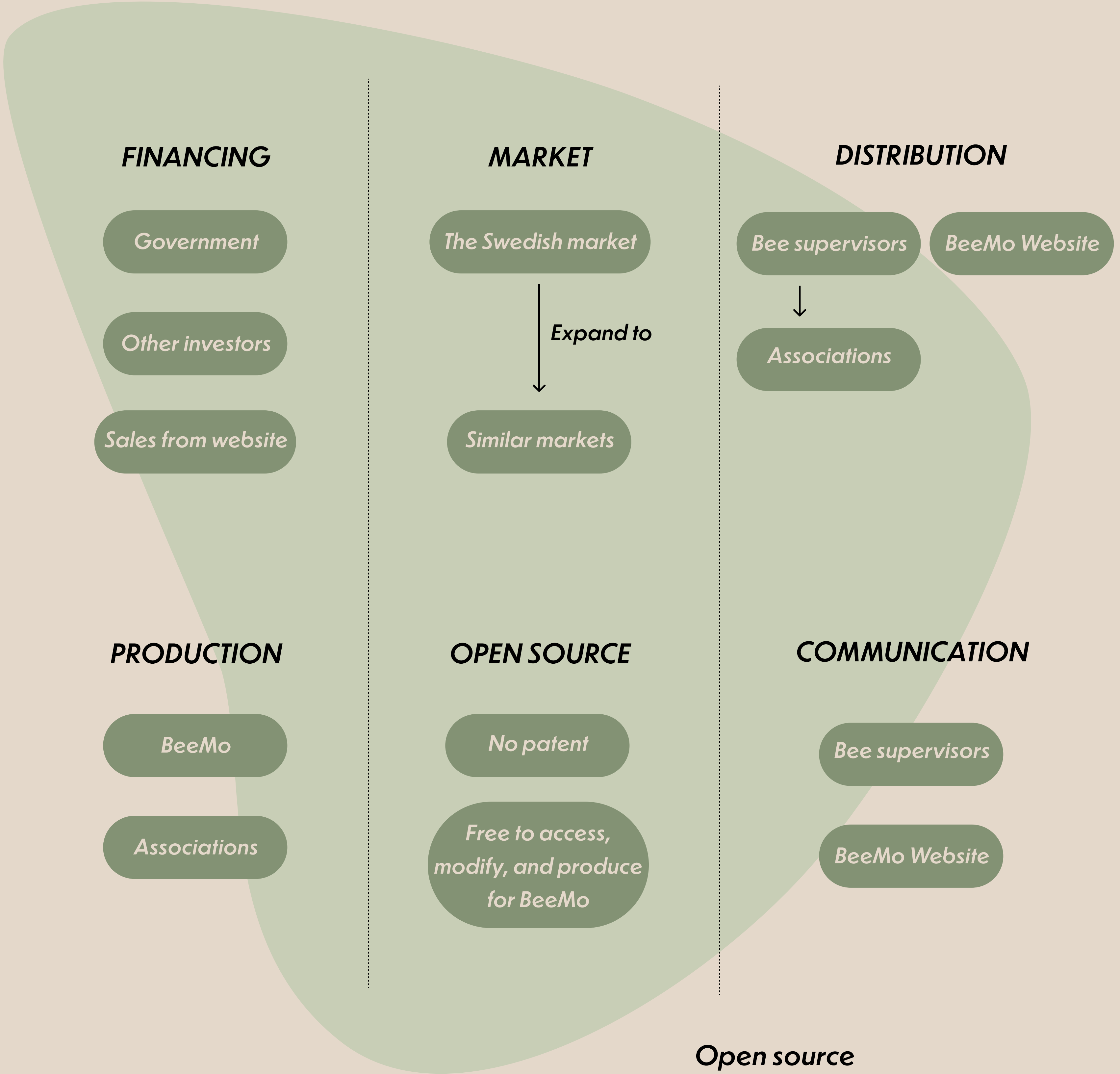
Financing for BeeMo is hypothetically mainly done through investors or governmental parties that seek to increase the awareness for our pollinators. Some revenue is collected through the website of selling and on demand distributing the product to beekeepers. However, the main ambition of BeeMo is not to make profit; instead, BeeMo aims towards being kind and aware of our precious environment; hence, BeeMo have initiated an Open-Source program.

Market

Begin with the Swedish market due to its applicability to its beekeeping industry. The Swedish market is a suitable starting point partially due to its size but also due to its well-established structure regarding beekeeping. In time, increased market size can be achieved through expanding to nearby countries of Sweden due to their similar nature and beekeeping industry.

Production

The production of the product consists of two streams. The first stream is through BeeMo, which produces and keeps a smaller supply of the product to be able to meet the demand from the Bee supervisor and other orders made through the website of BeeMo. The second does not include BeeMo as the primary supplier; instead, the product can be accessed and produced by beekeepers themselves (if the right equipment is available) with the help of BeeMo's Open-Source program. In addition, the production could also be made by other external parties that utilize BeeMo's product solution.



Distribution

There are two ways of distribution: Bee Supervisors and Bee Associations. The distribution system allows beekeepers to constantly have our product available on demand depending on the local need. All parties involved in the process (Bee Supervisor, Bee Association, and BeeMo) have a continuous conversation about what is to be delivered and to whom. One aspect of the distribution structure is utilizing the Open-Source function, which allows external parties to participate and further develop the idea/concept/solution of BeeMo. In addition, the product is also available through BeeMo's website, where customers can order by themselves on demand as they see fit.

Communication

Communication with BeeMo is done in primarily two ways. The first is through BeeMo's website, where beekeepers can talk/chat with designated personnel at BeeMo. The personnel assigned to the communication channel can assist the beekeeper in their need for answers to any kind of questions that may arise. The second channel of communication is through the Bee Supervisor which then can continue a dialogue with BeeMo if required.

Open source

For BeeMo, Open-Source is the possibility for beekeepers to free of charge access, modify, and produce any product of BeeMo by themselves as they see fit. BeeMo holds no patented right to the product and its design; instead, BeeMo allows external parties to access and further build upon what is initially created. The Open-Source program is constructed so that the BeeMo's solution may be distributed to as far an extent as possible to ensure better living conditions for bees, and also to increase the safety precautions for beekeepers.

3.4 Limitations

The system introduced in this report is a novel method to address the current the varroa mites' problem. It is, however, a conceptual design exercise that lacks of real world validation. Therefore, a comprehensive list of its limitations remains unfinished. Nevertheless, hereunder we include some aspects that can already be highlighted as possible drawbacks or limitations of the system.

The chemical

_the chemical proposed is currently only available for research use and lacks of homologation for its commercialization, at least in the E.U. If the total annual amount sold remains under certain limits, the process would be easier and would require less paperwork. On top of that, its effect on humans and bees' health has to be studied under for the concentrations in which it will be dispensed.

The material and manufacturing

_As pointed out in the design requirements, the material needs to have good recyclability, low price, suitable for the outdoors, and able to stand high temperatures to disinfect the drawer from time to time. 3D printing could always be an alternative for tech enthusiast beekeepers to DIY their own gates, or beekeeping associations to quickly print spare parts. The cost of printing the gate in a commercial 3D FDM printer using PLA as material and considering current electricity prices, for example, in Finland, would cost somewhere between 6€ and 9€. For mass production (thousands of units), the first option considered is plastic mold injection, which requires a much bigger investment in industrial machinery (tens or hundreds of thousands of euros). A more detailed business plan would be key for the final decision making in this regard. In conclusion, **choosing the correct material and manufacturing process** could be a whole engineering project on its own and **was not included in the scope of the project.**

Season regulation

_When the gate is added to the beehive, **it might still require some additional adjustments, for which we decided to rely on the DIY skills of the beekeeper**. Beekeepers have proved themselves active and creative in engineering their own solutions for their beehives, making us believe that there is no one better than themselves to perform the final adjustments and fitting. The only downward of this approach is that the user might perceive it as a low-quality ending of the product that adds extra steps to the process.

Tech module space

_the space dedicated to the tech module is quite limited in height and width. This can be an issue when implementing new technological solutions and is seen as one of the main limitations for the overall system in attracting third parties into building their own modules for the system. One option is to make a bigger module that is not removable along the drawer and which requires to remove the whole gate each time that has to be inserted or removed. This would interfere with the ergonomics and user experience and should be studied more in detail.

4.

Conclusion

After eight months of work the project has officially concluded. During this time knowledge has been gathered, users interviewed, ideas generated, prototypes tested, and a final concept developed within the limits of our resources, these including skills and time. The final outcome is a proposal for a modular system that aims to be spread among the beekeeping community to tackle wicked problems they face as well as upcoming problems that are just starting to show their effects.

Impact of the project

The outcome of the project gives hope to beekeepers. With our solution, each year thousands of Nordic beekeepers could save their declining colonies and reduce their economic loses. This translates in a stronger, more stable and resilient industry. For people for whom beekeeping represents a main or secondary source of income it also represents greater stability and possibility of develop a better future. Despite designed to be implemented first in the Nordics, we foresee that our platform could be used in other geographical areas as well.

The group of stakeholders in the beekeeping industry could expand thanks to tech companies entering the market with their proposals for the tech module, digitalizing the industry and opening the door to future innovations.

Furthermore, the reduction of pesticides used would positively affect the environment, reducing toxic particles spread into the environment.

Next steps

The next step for the project would be to research the chemical proposed. This is because its effectiveness has to be proved. It also has to be studied its effect on bees' behavior. On top of that, possible effects on the user's health must be clarified and a process to achieve the final market form factor has to be developed. Once it has been proved to be safe and effective it has to be homologated for commercial use, at least under European union standards.

To research this, we would propose to contact a university chemistry department so that they can offer a thesis or research on this topic. If all the above-mentioned obstacles are overcome, the next step would be to involve business and entrepreneurship experts to plan and ultimate details regarding the business model and ensure its economic feasibility.

We see in Aalto the perfect ecosystem to carry out all these future development phases for the project. The chemistry department could be contacted to carry out the research on the chemical. Volunteers from the Creative Sustainability program at Aalto manage beehives in which potentially real-world tests could be carried out if they agree to collaborate. A helping hand regarding the business plan could be provided by Aalto Ventures Program and Start-up Sauna.

5.

Appendix

References

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[2] - Nazzi, F., Milani, N., & Della Vedova, G. (2004). A semiochemical from larval food influences the entranceof varroa destructor into brood cells. Apidologie, 35(4), 403–410. https://doi.org/10.1051/apido:2004023

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Prototypes booklet

In the following pages the reader can find more information about all the prototypes mentioned in this report.

Modified bees

01

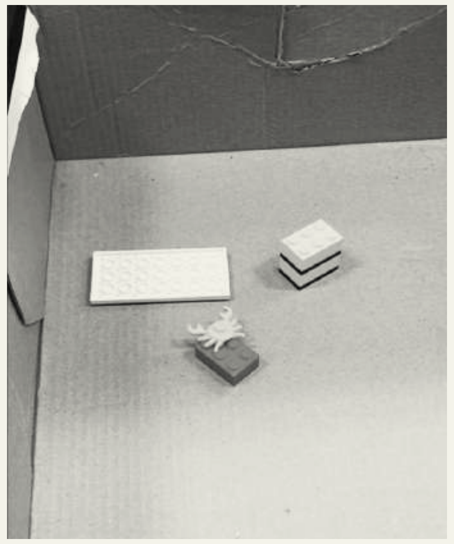
Story

As a natural habit of bee society, bees put a guarding bee in the beehive's entrance to govern who enter or not. However, the bees need to be protected from American Foulbrood (AFB) since it harms the eggs produced by the bee queen. What if this guarding bee could stop infestations such as AFB from entering the beehive? By either an evolutionary development or a genetic modification of the bees, this prototype showcases how they can protect themselves.

The research and ideation that got us to modify the bees were mainly the constantly mentioned problem of managing infestations, in this case, AFB. AFB forces the beekeeper to constantly check up on their beehives, not to check on the level of honey produced or similar, instead they have to regularly be aware of their bees' health condition so that outbreaks of AFB occur. If a beekeepers' beehive by chance becomes infested, then there are not many other options than burning it all down. Hence, our idea of modifying the bees to withstand AFB without supervision by the beekeeper came to mind.

Feedback

The only way to test this prototype was to use genetically modified bees which raises ethical questions. Hence, we only had a discussion within our team and tried to ideate how such a solution would influence both the bees themselves, and also what it would mean for the beekeeper.



Learnings

To genetically modify bees may be possible but due to ethical reasons, we believe that there are other better options that might derive similar outcomes.

Detecting AFB On the Go

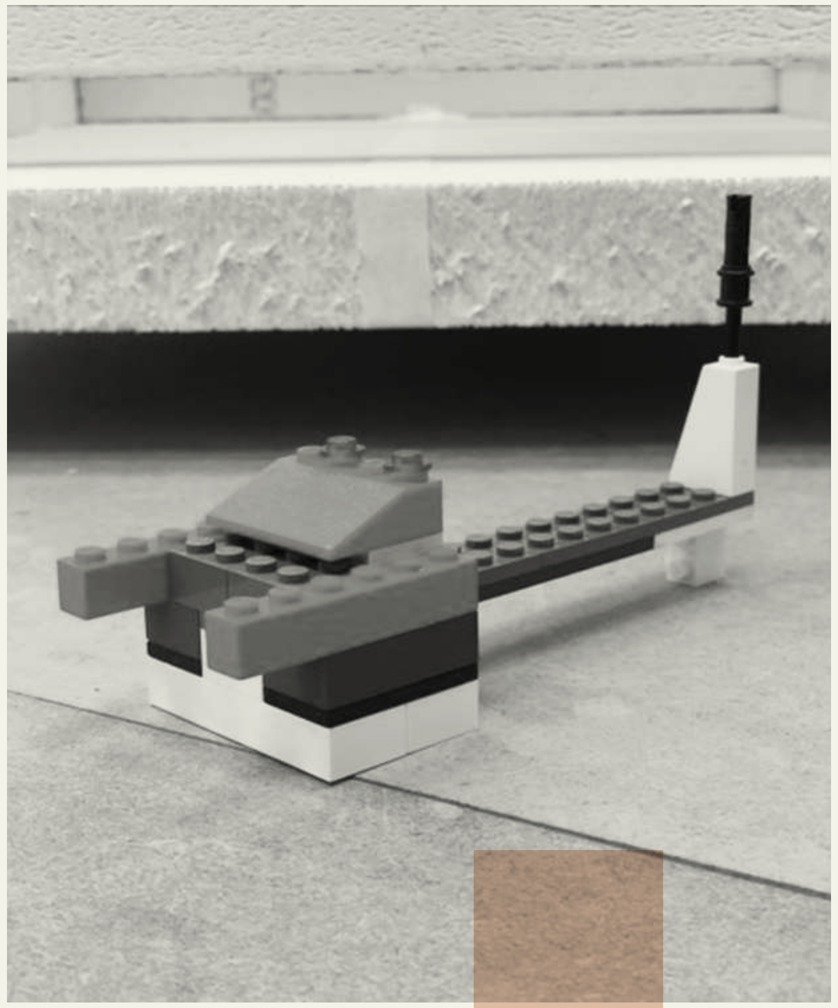
02

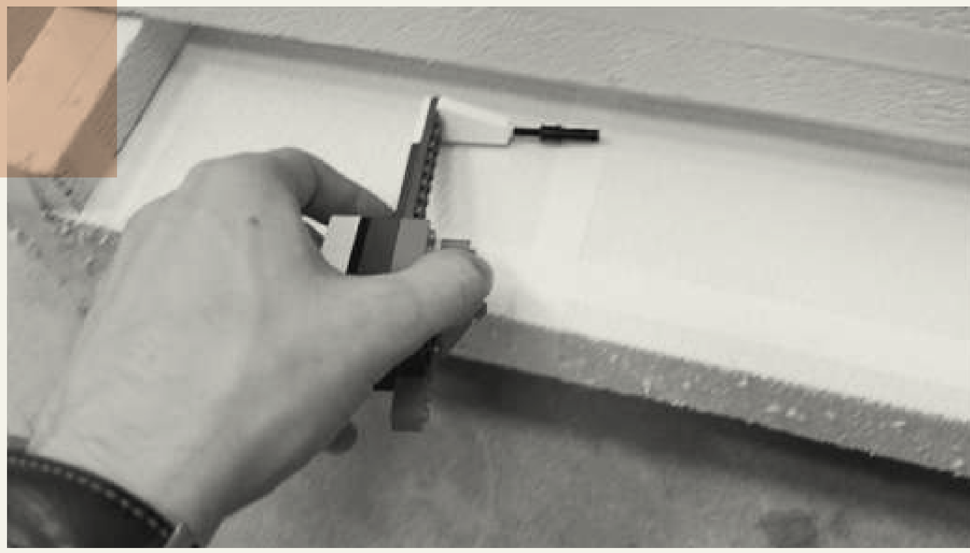
Story

This prototype goes in line with the previous one but instead of fighting American Foulbrood (AFB) outside the beehive through the entrance, bees would be modified to fight AFB inside the beehive. Bees could either fight it physically or by producing a substant that would terminate the AFB on the inside, but the idea of this prototype was mainly to be able to detect AFB easily on the go at an earlier stage. Detecting AFB earlier would mean that it could be possible to save the beehive from extinction; hence, also providing easier monitoring for the beekeeper.

Feedback

Since this idea partially requires modification of the bees, we could not test it. Instead, we discussed it within the group. However, we have had a conversation about how it would be possible to make such a detection system function with beekeepers, but the response was pessimistic due to the infestations' direct and swift impact on the bees and the beehive.





Learnings

As the pervious prototype, we learned that genetically modifying bees raises questions regarding ethics, thus, we decided that there are other better options to go with. Although, as for the detection system, we tried to apply the idea of this concept to other ideas and other infestations which have proven to be more easily treatable.

Detecting Varroa on the go

03

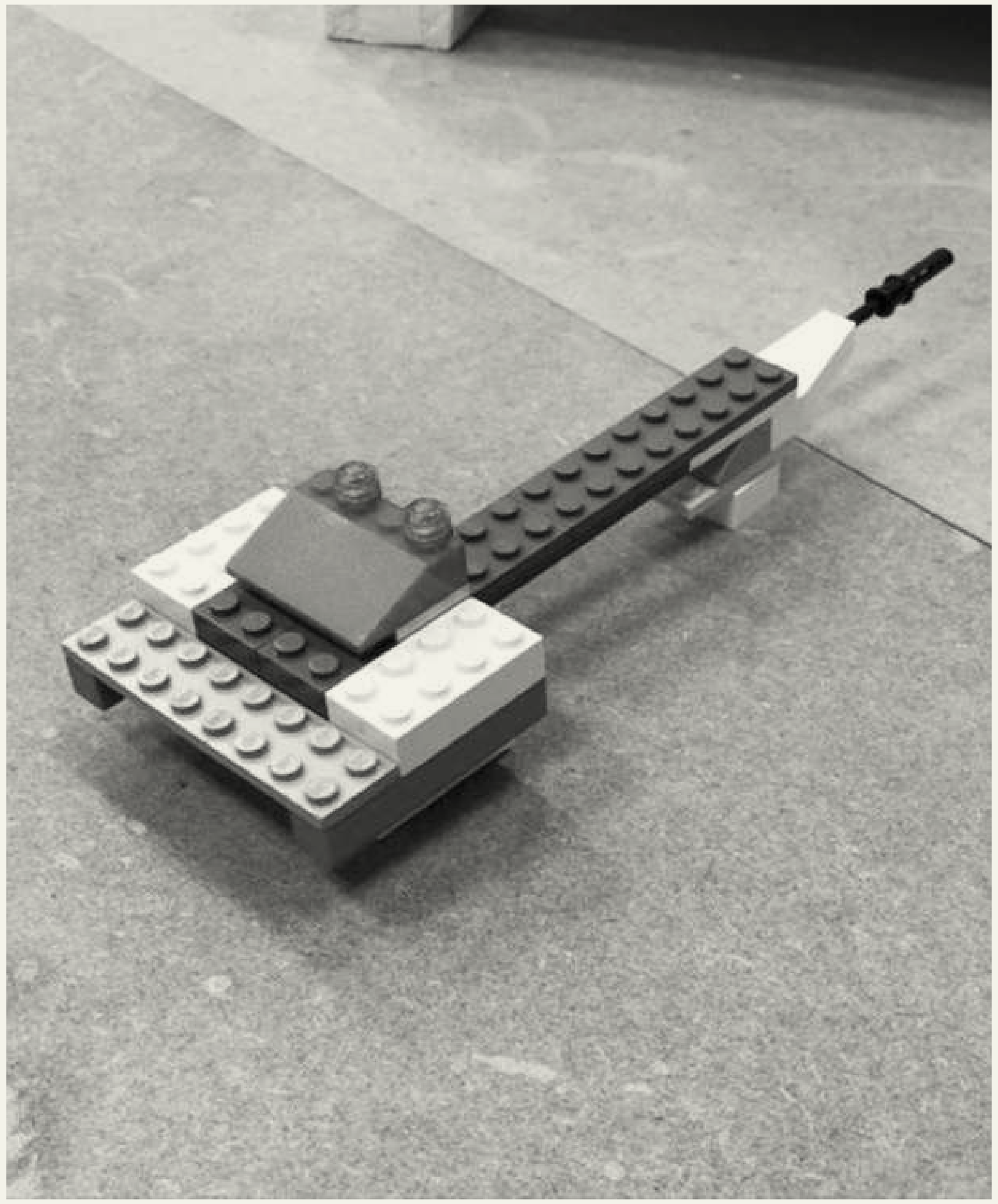
Story

Today, beekeepers go through various different processes when monitoring and treating Varroosis. Many of the tools and strategies the beekeepers must manage Varroosis are outdated and complicated. Speaking with beekeepers, it is stated that some beekeepers have left the field of beekeeping solely due to the unnecessarily demanding task of fighting off Varroosis. It was realized at an early stage that beekeepers would need some more efficient tools when it comes to managing infestations, in this case, Varroosis.

Through extensive ideation sessions, Detecting Varroosis on the Go (DVOG) was created. DVOG was an early-stage prototype of how to assist the beekeepers in their daily or seasonal tasks of managing Varroosis, which would ease the burden for beekeepers, but also save the many lives of bees. By being able to efficiently detect Varroosis on the go, DVOG was created to aid both the bees and the beekeeper.

Feedback

"This device may irritate the bees and it still requires a lot of effort. To scratch it against the beehive's inside, you need to lift each box down which requires heavy lifting. Also, the bees will not enjoy having this device inside, which could become a danger for the beekeeper"



Learnings

We learned that there is a need to continuously detect Varroosis but that this device does not necessarily enhance the detection for the beekeeper. An experienced beekeeper will detect it much easier with just the eyes or other more traditional equipment.

The bee app

04

Story

Just as for one of the previous prototypes, The Bee App desire to detect the level of Varroosis inside the beehive. Beekeepers have expressed the need to identify the level of Varroosis inside the beehives and this application, The Bee App, meets this desire. By scanning the frames, the app can identify the level of Varroosis through algorithms. The idea of the application is partially for more experienced beekeepers to be assisted in their tasks, but also for the more inexperienced beekeepers to easier learn how to detect Varroosis and to be able to give ethe bees the proper treatment.

Feedback

Since the app is not developed, we tested the app's desirability by using it ourselves and discussed a version of it with one beekeeper who proclaimed that the application could be of use for some, but that it might suffer from becoming obsolete too quickly.

Learnings

Through testing, we realized that the app enhances calculating the level of Varroosis but that the process of using the app still requires all manual work: the beekeeper still needs to open the beehive, take all the frames out, and conduct a complete interaction with the beehive as per usual.

Societal awareness in urban areas

05

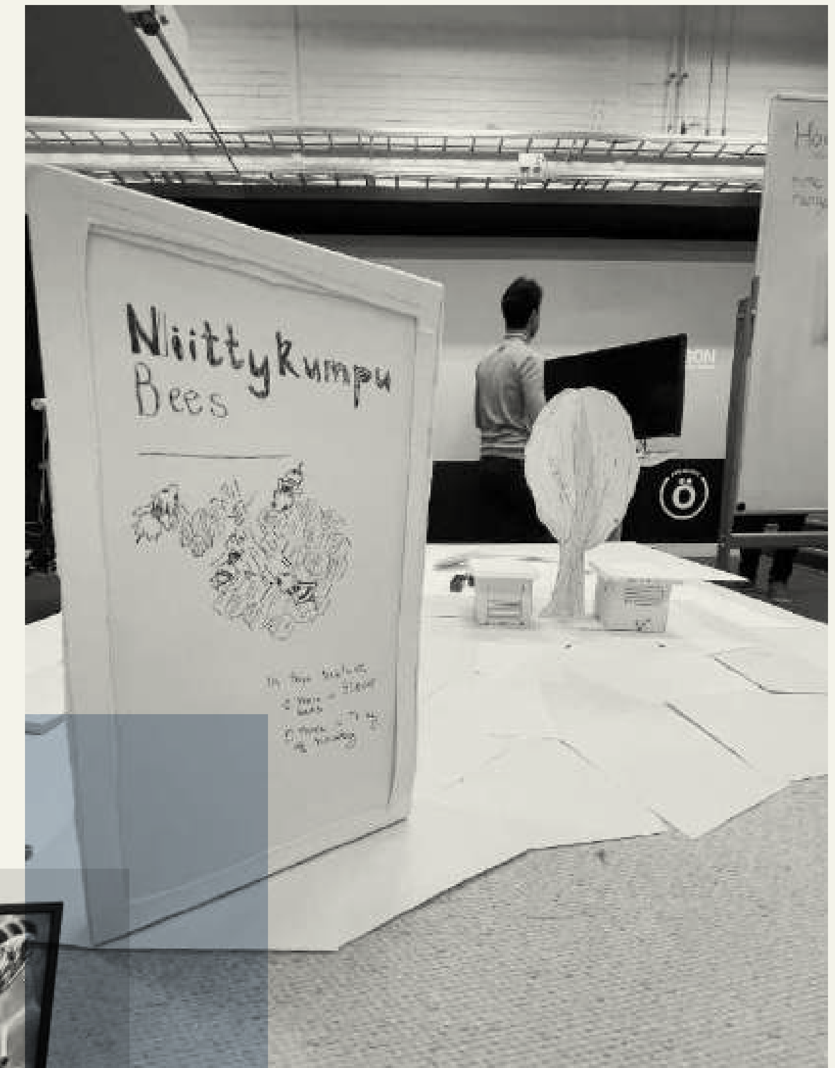
Story

This prototype was based on our own relationship with bees. As beginners in the topic of beekeeping, we lacked the necessary expertise to design complex solutions. Instead, we defined our target group based on our experiences with bees. Based on this, we decided to address the common public's unawareness of bees and beekeeping.

Our prototype consists of a digitally monitored beehive and a screen. The beehive collects data and visual materials of the hive and forwards them to the screen where the information is curated to raise awareness of by-walkers. This solution would be placed in public parks. The aim of this solution is to promote the co-existence of nature and people in urban areas.

Feedback

This prototype was tested on our classmates and course teachers. Our testers expressed that they did not like seeing bees on a big screen. Specifically, they were disturbed by close-up videos of bees and larvae. Some testers mentioned that they already had a fear of bugs and that the videos were making them uncomfortable. However, the testers enjoyed reading facts about bees that they did not know before.



Learnings

From this prototype we learned valuable insights about the emotions that bees can provoke in people. In this case, our target audience (non-beekeepers) were uncomfortable about seeing bees. However, this might have also been influenced by our audience's detachment from nature (which would prove the need for raising awareness in that matter). Thus, we came to the realization that if we were to design for beekeeping in urban areas, we would have to consider non-beekeepers' relationship with bees as well.

Beekeeper wellbeing simulation

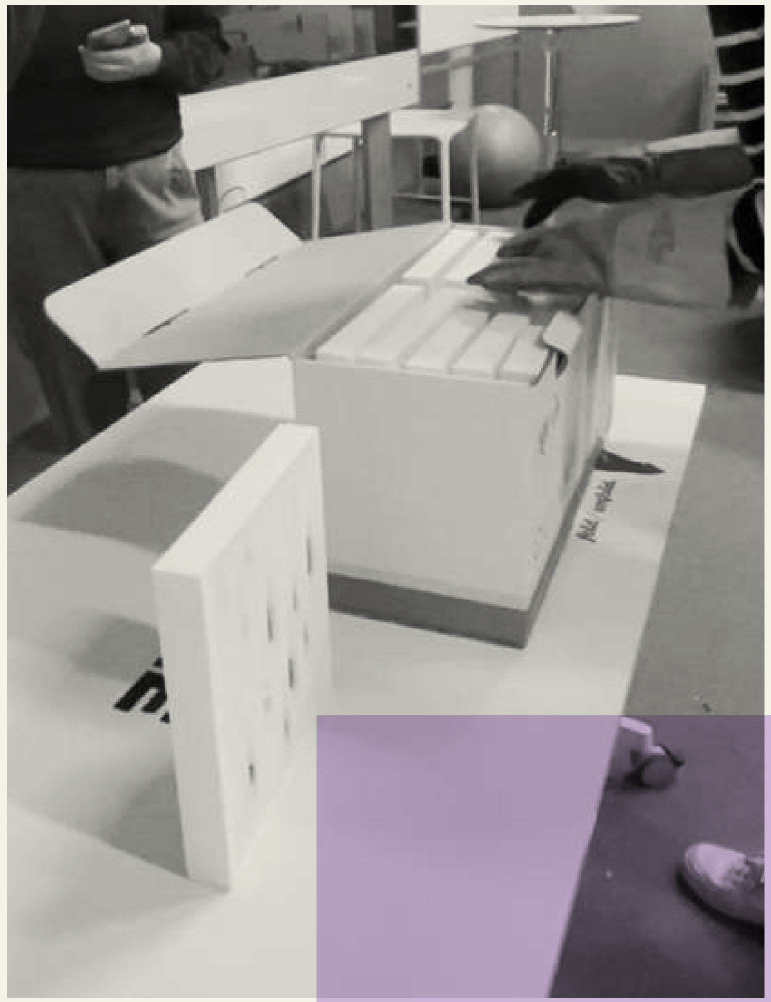
06

Story

We wanted to explore beekeeping from a beekeeper's viewpoint to further understand what emotions beekeeping could provoke in a professional beekeeper. For that, we created a beekeeping simulation that consisted of sound and physical experiences. In this prototype, our tester had to wear a vision-blocking mask, a headset and big gloves. The task of the tester was to approach a beehive, open it and remove honey (lego pieces) from the frames. Furthermore, we made the task challenging by playing loud bee sounds from the headset.

Feedback

In this simulation, our testers noticed that they were at first bothered by the loud bee sounds and the uncomfortable equipment (the gloves and the mask). However, the testers expressed that after a while, they got used to their surroundings and were able to continue their tasks more easily. Our testers were able to ignore the distractions once they started to focus on the tasks that needed to be completed.



Learnings

Through this simulation we learned that experienced beekeepers most likely develop a skill of concentration on the tasks that need to get done. Although some tasks may take long due to inconvenient safety equipment, it is possible to ignore the bees flying around and making noises. Furthermore, this prototype allowed our team to understand better the experience of beekeeping.

Temperature adapting systems
07

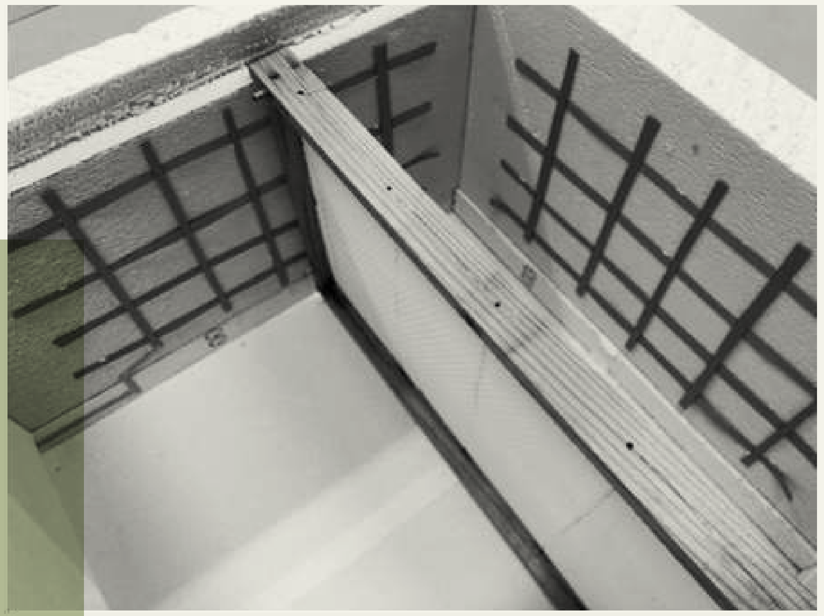
Story

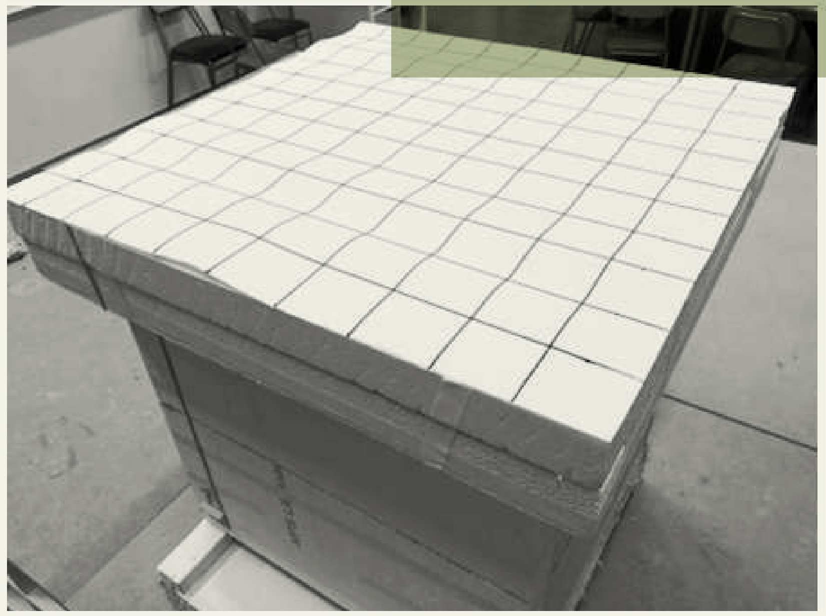
The story behind the temperature adapting system has its foundational aspects in climate change and its impact on bees and bees' survival. Depending on the season, the bees might suffer from a beehive that becomes too low in temperature or a beehive that is on the contrary too high in temperature. What causes issues for the bees is the constant fluctuations in the temperature because it confuses the bees' natural instincts and disrupts their natural order.

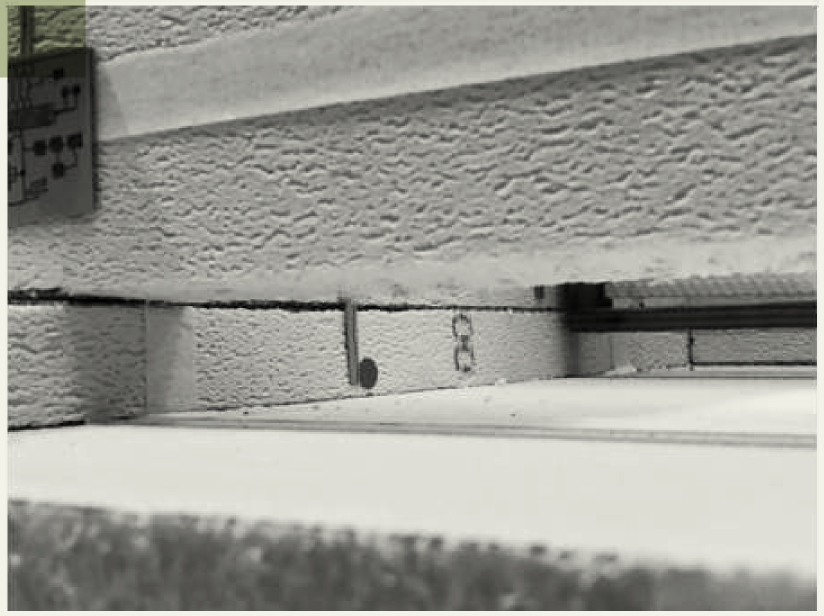
The temperature adapting system could then solve the issue of having confused bees, or a beehive that is at a temperature that lowers the level of honey production. The system would also mean better living conditions for the bees in the ever-changing world we nowadays live in.

Feedback

The feedback received from beekeepers has been optimistic because they mean that it could benefit both the bees and the beekeeper. However, the beekeepers also stated that it is important to re-think how much we should actually interfere with the bees' natural order and where to set the limit.







Learnings

For this prototype we had valuable insights and learnings in regards for how much we should disturb the bees when applying our solution.

Track infestations

08

Story

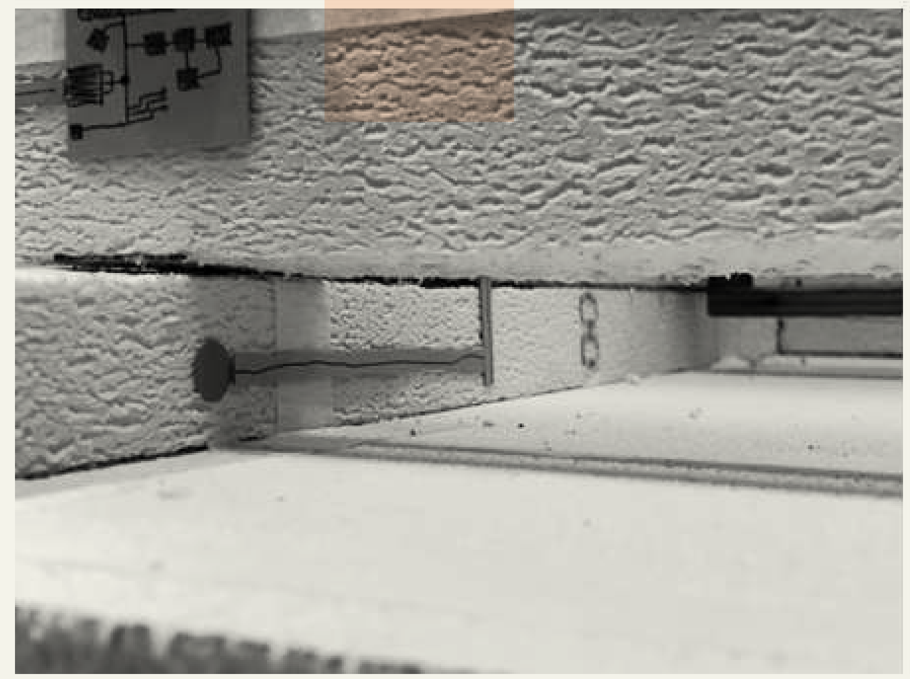
As the tremendous harm that Varroosis has on bees was clear at this point, the following "what if" questions regarding Varroosis was further taken into consideration for this prototype:

- ***What of there was a way to detect Varroosis with the help of sensors?***
- ***What if it was possible to surpress Varroosis with the help of sound?***
- ***What if there was a way to be able to track the levelof Varroosis within the beehive?***
- ***What if there was a way of terminating Varroosis withouth using acids that eventually stockpiles in the bees' wax?***

With these questions in mind, we created a prototype where a sensor was placed in the ntrence to detect Varoosis. The sensors could hypothetically be sensing chemical, light or gas variations. When the sensor is triggered, the sensor in turn triggers soundwaves in a length that Varroasis does not appreciate but bees can handle, in a similar way as mice can be kept away with ultrasound.

Feedback

When this prototype was tested, most of the feedback was positive. The idea of a solution without using chemicals was appreciated. It was mentioned that the prototype works in theory, but the beekeeper questioned the amount of studies that must be made to ensure that the Varroosis reacts as desired to the soundwaves and how to control that the Varrosis decreases due to this.



Learnings

One of the main leanings we brought with us from this prototype was that the Varroosis does not only effect the bees but also the Beekeepers to a large extent, as one beekeeper mentioned during the testing that some of his beekeeping friends had stopped beekeeping due to the complicated way to treat Varroosis. Moreover, the insight of how difficult it is to keep track of the amount of Varroosis was highlighted, as this is a matter of manually counting the Varroosis that has died after treatment.

Space beehive

09

Story

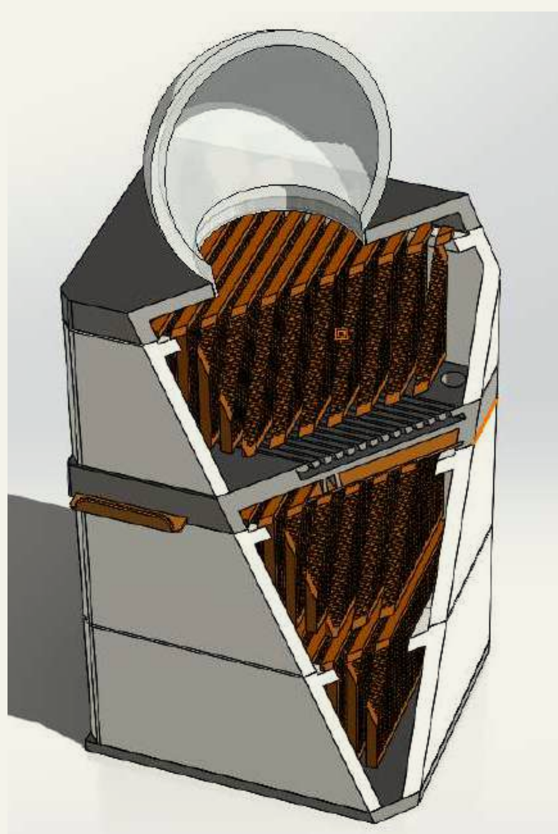
This prototype was our exploration into the limitations and possibilities of beekeeping practices. We wanted to experiment with minimum bee living conditions, find alternative approaches to beekeeping from traditional ways, and create new avenues for beekeeping as an industry. Our first steps into this exploration led us to experiment with bees in space.

Due to climate crisis on the Earth today, we as humans are constantly exploring new ways of life. One of these explorations is happening to create life in space. As species on Earth are dying from radical climate change, scientists are looking for ways to develop living environments for animals and nature in space. Thus, we asked ourselves, if bees and other pollinators are dying on Earth, would there be a place for them in space? What kind of living conditions would honeybees need to survive in space? How could we make beekeeping possible in space?

Based on these questions, we built a prototype of a space beehive. In this prototype, the beehive was placed in a space garden against a door system. The bees would use the plants to gather pollen and make honey. The plants would be pollinated by the bees. Furthermore, to ensure the safety of the spacestation, the beehive could be accessed and harvested without any contact with bees. In case of a harvest, the astronaut would simply activate an airflow system in the hive that would close the hive exits and blow bees from the honey box into a sugar bubble. Then, the astronaut would pull out the honey box through a shelf system to harvest the honey.

Feedback

For this prototype we mainly received feedback regarding the necessity of this solution. For instance, a rocket scientist who helped us with gravity calculations asked whether other food sources on space stations would not be easier to upkeep and interact with. Moreover, our course teachers pointed out that honey can already be produced by processes that do not require bees. Thus, it could be concluded that the benefits of bringing bees to space should have been better stated.



Learnings

The space beehive prototype allowed us to explore alternative avenues of beekeeping. Through this process, our team was able to understand the essential bee living conditions better and also get started on designing new shapes and forms for beehives.

Post-apocalyptic beehive

10

Story

The post-apocalyptic beehive was an exploration of the possibilities of bee living conditions. In this Dark Horse prototype, our team asked the question of what if we did not have access to professional beekeeping equipment. How might we accommodate bee colonies with available materials whilst still achieving thriving bees?

The idea of a post-apocalyptic beehive sets us into an environment where we would only have access to materials around us. In a post-apocalyptic world we are focusing on survival and cannot think of providing the best conditions for bees.

The prototype of a post-apocalyptic beehive was thus built with a DIY (Do-It-Yourself) mindset from plastic bottles, wood scraps and simple ribbons. The construction of the beehive was inspired by the method of bottle-to-bottle beekeeping.

Our post-apocalyptic beehive is easy to assemble and can be used for multiple purposes: 1) to capture wild bees; 2) to harvest weekly honey (smaller bottles on the side; and 3) to transport bees between locations.

Feedback

This prototype did not receive a lot of feedback because the beekeepers we reached out to had never come across the bottle to bottle beekeeping method. However, this prototype gained traction among non-beekeepers as a possible DIY project to start beekeeping.

Learnings

Whilst working with this prototype we learned to deconstruct the structure of beehives and make modifications by keeping only the crucial elements of the hive. Furthermore, our research on the topic revealed to us a lot of requirements that bees have in order to become a thriving colony.

Individual pest control

11

Story

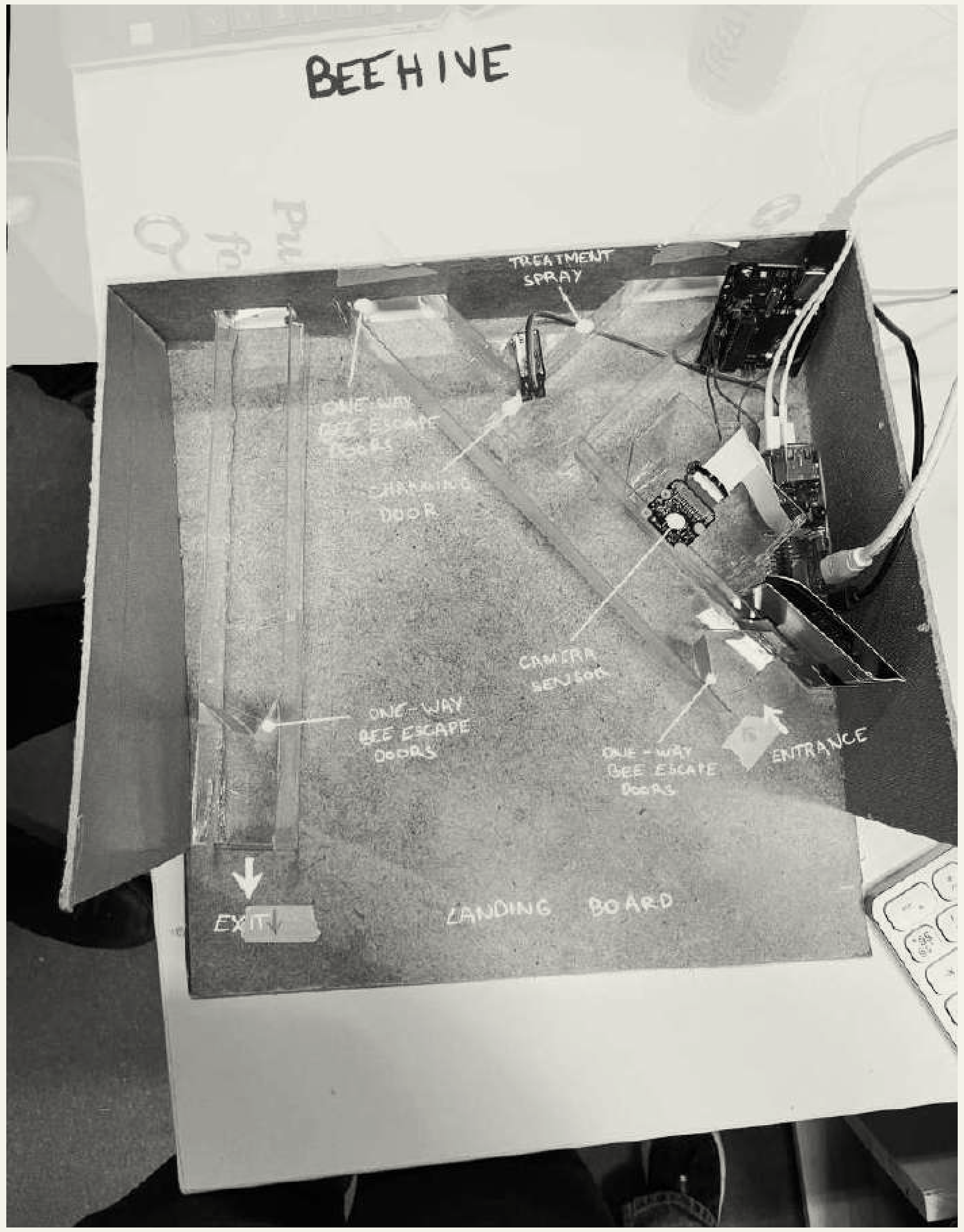
As earlier mentioned, the presence of Varroosis has been pointed out as a critical problem for both bees and beekeepers. That is why we decided to further explore how the varroosis could be minimized and the pros and cons from the earlier developed prototypes considering Varroosis was taken into consideration. One thing that the beekeepers had expressed was the problematics with the great amount of non-environmentally friendly acids that are used when treating the hive against Varroosis during the fall.

We decided to make a system that could both detect and treat Varroosis. In this prototype, we played around with the entrance. We made the entrance to a tunnel with swing doors that ensured that the bees were only able to go in one direction. In the tunnel, a camera was placed. The vision was that a Neural Network could be trained to be able to detect whether the be was carrying Varroosis or not. The result triggered a door to switch direction which allowed the bee to either enter the beehive if the bee is free from the mites, or the bee walks into another tunnel where the bee is individually treated with the chemical.

This solution decreases the amount of chemical that is used as well as allows for the beekeeper to track the amount of Varroosis that is in the beehive.

Feedback

The feedback received from this prototype was positive and the fact that the beekeepers could monitor the bees, reduce the amount of chemicals and ease the treatment was appreciated. Furthermore, one beekeeper pointed out that this solution could even be implemented all year around, as the chemicals won't be in touch with the beehive so that the honey won't be affected by the treatment. This is also beneficial since the Varroosis are thriving during the spring and summer, when conventional treatment is not an option.
We also got some really edible feedback, mainly concerning the individual treatment. Questions like, what chemical can be used? How long does it take before the bee is free of varroosis? Where will the bee go after it has been treated? were brought up.



Learnings

This was the first prototype where technology was properly incorporated. In regards of competence, we discovered that if we would like to further develop a high-tech solution the whole group needs to try to get a deeper understanding of the technology to spread the workload. In regards of the prototype itself one learning is that the tunnel system works well in beehives and that bees learn very quickly. Moreover, we discovered the weight of having a well-chosen chemical for the treatment, as the whole solution is dependent on it.

Thermoregulated beehive

12

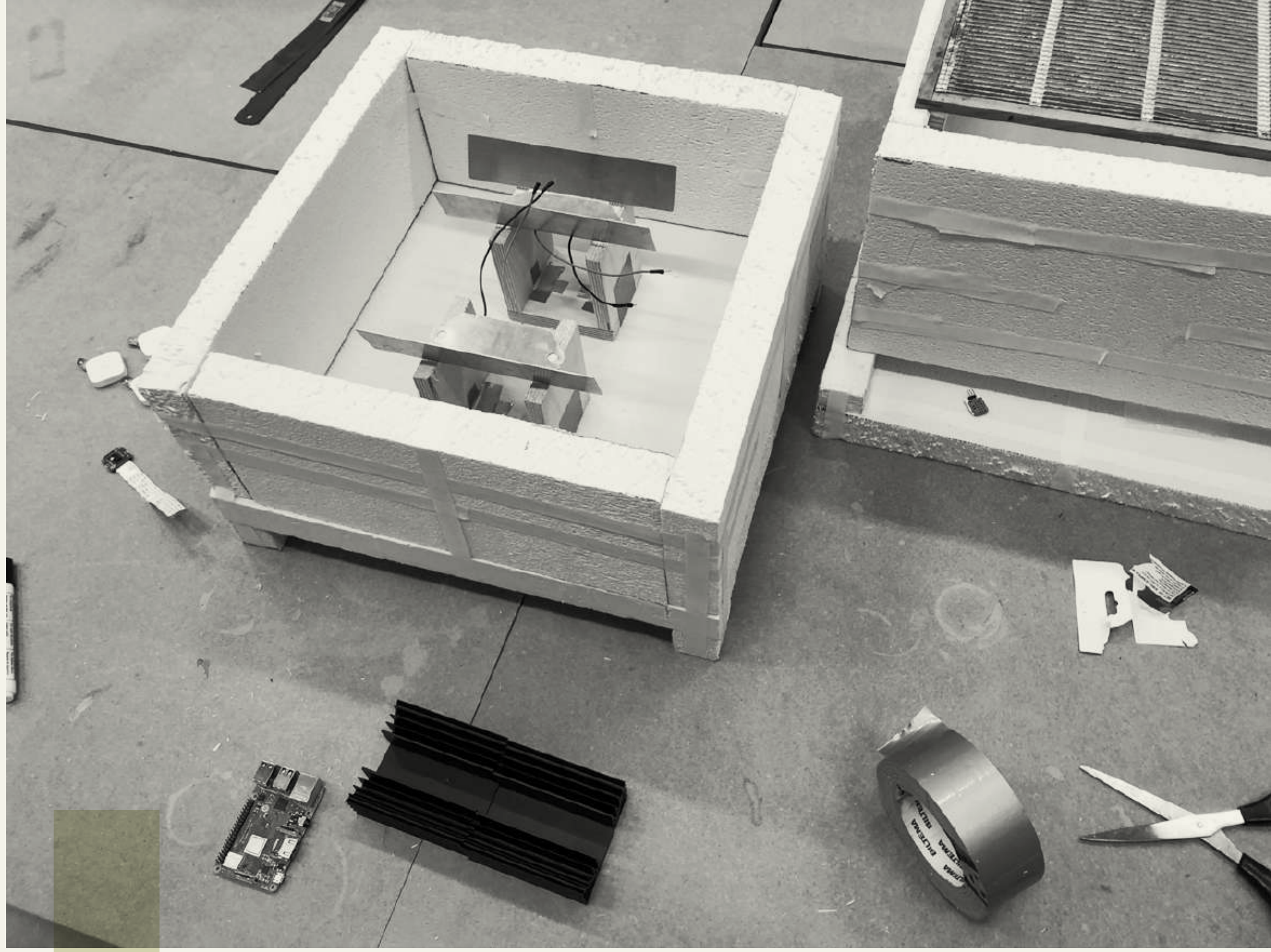
Story

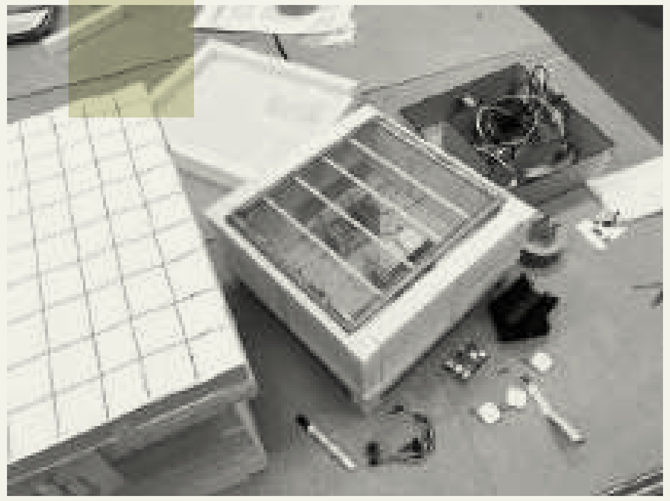
Climate change has caused high temperature fluctuations which affects the bees' sensing of when to pollinate. This means that the bees can be ready to pollinate too early when there is nothing to pollinate and vice versa. Thus, this prototype aims to regulate the temperature inside the beehive to avoid early pollination. Within the fluctuating environment that we nowadays live in, the Thermoregulated beehive serves the purpose of aiding the bees in their effort in understanding the appropriateness of the surrounding environment.

Based on research about how bees' behavior is influenced by high or low temperatures led us to investigate this matter. We desired to understand how the bees are affected and what could be possible ways of encountering this issue; hence, the Thermoregulated beehive was created. Understanding the fundamental pattern of how bees function depending on the season made us realize that this sort of solution could be a beneficial attribute and tools for both beekeepers and the bees themselves.

Feedback

The feedback and response when showcasing the idea for beekeepers were sort of optimistic; however, beekeepers did mention that it is important to question to what extent we should tamper with the laws of nature. Bees have been around for hundreds of years and have all survived for this long, which raised the question of whether or not this solution would contribute with enough benefits to be worth making a reality.





Learnings

The bees are tough animals and can adapt pretty good to climate. Referring to what was earlier mentioned based on the feedback received from beekeepers, one main learning point from this solution that will bring us interesting arguments in our upcoming journeys is that it is of significance to really understand on what level bees and beekeeping should be altered. What is a suitable level of influence from our solution to how beekeeping has been conducted up to today and how can we know for sure that we are not overdoing something that might only cause harm? We are not stating that this solution and idea is harmful; however, it is of incredible importance to understand what the unknown consequences may be from our particular solution.

Varroa trap gate

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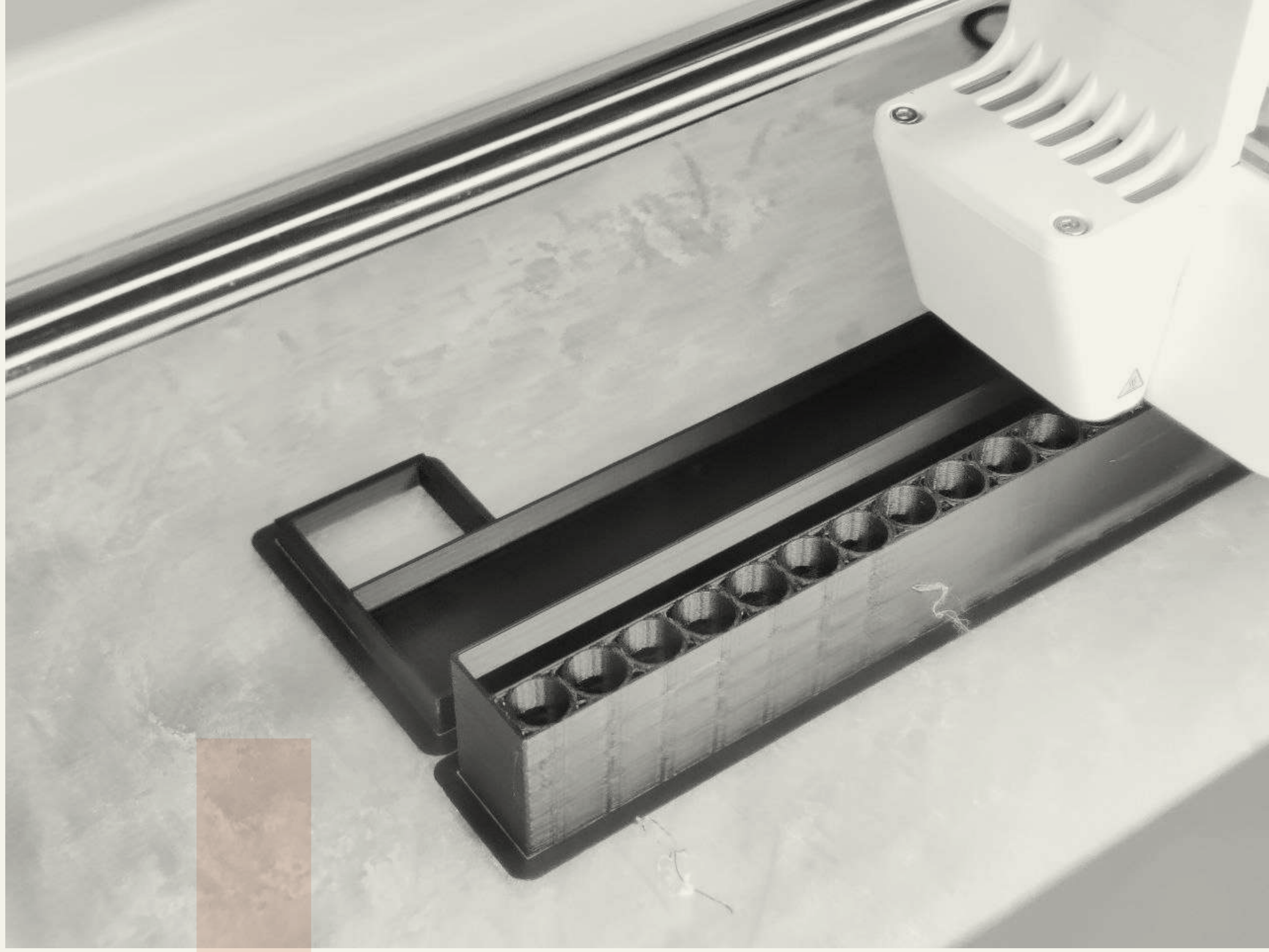
Story

It has been stated by beekeepers that various infestations trouble the job of the beekeeper, making it increasingly complicated. Due to the increased complexity of managing infestations amongst beekeepers, it has been proclaimed that it would be of tremendous assistance if there was an easier way of dealing with these issues.
Based on research and discussions with numerous beekeepers, it was decided that we should focus on managing infestations and parasites in beehives. More specifically, our team decided to focus on an increasing problem in the industry- Varroa mites. The Varroa mite is a smaller pest that hangs on to the bees, preferably on their back, making it difficult for the bees to live a normal life. The Varroa mite also complicates the job of the beekeeper, forcing them to use pesticides that are usually not too good for the environment. This is where the Varroa trap gate comes to play a crucial role in our journey of improving beekeeping.
The Varroa trap gate is a modern way of improving bees' survival and easing the burden for beekeepers. The main aim of the Varroa trap gate is to minimize the usage of toxic chemicals in the process of fighting off Varroa mites. The Varroa trap gate is used as follows: 1) the gate is placed at the entrance of the beehive; 2) then a small amount of special chemical is placed on a tray below the entrance tunnels ; 3) the Varroa mites will smell the chemical and drop into the tray. Through this process we believe that we could prevent most of the Varroa mites from getting into the hive.



Feedback

The Varroa trap gate received optimistic responses and feedback from the beekeepers and other stakeholders that were interviewed or talked to during the process. It was stated that the idea of this solution to the problem would practically help beekeepers in performing their job to its full potential. By implementing this solution, it would be possible to fight Varroa mites earlier in the season and not solely towards the end during the autumn. It was also mentioned by beekeepers that this solution would open newfound possibilities of dealing with infestations, with the assumption that the new chemical used in the trap gate becomes verified and allowed for general use.

Learnings

Through extensive discussions with beekeepers, we found that our solution could respond to the initial challenge that was given to us at the beginning of the project. We also got an insight into how we could further develop the idea and what questions need to be considered along our journey. We realized that we had to be considerate about how we implement this solution, how to make it adaptable to various models of beehives, and how to create this solution in a way that makes it comfortable for the bees. It is also important to mention that this is the idea that has triggered our minds to think about modularity for real, and how we could make use of this when further developing our different ideas.