SMART INDOOR GROWING SYSTEM

GRADUATION REPORT-INTEGRATED PRODUCT DESIGN

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EXECUTIVE SUMMARY

For many people, limited living space, lack of knowledge, and challenging indoor conditions make it difficult to grow their own food. Beginner gardeners often struggle with questions such as when to sow, how much water plants need, and how to maintain healthy growth. While many existing smart growing systems address these issues through extensive automation, they are often expensive, technically complex, and reduce user involvement. As a result, users learn little about the growing process because the system takes over most tasks instead of supporting learning.

This project presents the Smart Indoor Growing System: a compact, modular indoor growing solution that combines a physical growing frame and tray with a supportive app. The design focuses on guiding and educating users rather than fully automating plant care, allowing users to actively engage with the growing process while receiving clear feedback and support.

Overall, the Smart Growing System demonstrates strong desirability by addressing real user needs for learning, accessibility, and space efficiency. The final design includes a fully wooden, modular frame with fixed-length posts, a slide-in mechanism for compact storage, and integrated LED lighting with a fixed timer. The growing tray features a raised edge, a lid that fits inside the base, a moisture sensor with four levels, and a removable inlay suitable for multiple plant varieties and P9 pots. The product enhances sturdiness, usability, and intuitive interaction, while supporting the growth of a wide range of crops in limited indoor spaces.

Material and production choices were guided by feasibility, sustainability, and cost-efficiency. Pinewood, Birch, and polypropylene ensure durability, low environmental impact, and scalable manufacturing. By combining injection moulding and thermoforming, the system can be produced efficiently at scale. With an estimated production cost of approximately €47 per unit, the product remains significantly more affordable than most existing smart growing systems, strengthening its market viability.

The accompanying app provides step-by-step guidance, sowing and harvest calendars, notifications, community interaction, and includes a feature for assembling the frame, further supporting active learning, user confidence, and a seamless user experience.

Overall, the Smart Indoor Growing System demonstrates strong desirability by addressing real user needs for learning, accessibility, and space efficiency; feasibility through validated materials, production methods, and tested mechanisms; and viability through affordable production, modular scalability, and sustainable material choices. The project introduces a meaningful alternative to fully automated systems by creating educational value, encouraging sustainable behavior, and strengthening users' connection with food production and nature.

PREFACE AND ACKNOWLEDGEMENTS

Dear reader,

With this final thesis, I bring both my graduation project and my studies at TU Delft to a close. After five and a half years of learning, experimenting, and developing as a designer, this thesis represents the final milestone of my academic journey.

My interest in this subject began about two years ago. I was walking through a garden center with my partner when we came across a small growing table and some lettuce seedlings. We decided to start sowing all kinds of plants and placed them on my windowsill (top left images). At that time, we were mostly experimenting without really knowing what we were doing; about half of our attempts failed, and we did not fully understand how the growing process actually worked. What started as a small growing table gradually developed into a larger planter for tomatoes in my parents' garden. The tomatoes secretly turned out to be very dry, but the feeling that we had grown them ourselves together was indescribable (top right image).
When I moved in together with my partner a year later and we got a large garden, I began to read more about gardening and our harvests improved significantly. I noticed how happy I became from all the fresh vegetables growing in the garden, and how delicious they were (bottom images). From that moment on, I knew that I would love to share my enthusiasm with others while continuing to learn more myself.

First of all, I would like to thank my client, Simon Eurlings. He always took the time to speak with me and truly listen. His input was extremely valuable throughout this project and provided me with many new insights.
I would also like to thank my supervisors, Adrie Kooijman and Jotte de Koning. I always experienced our meetings as pleasant and constructive. You were always willing to listen and provided feedback that helped me grow as a designer. You challenged me to think in new ways, and I learned a great deal from our collaboration, thank you very much.
In addition, I would like to thank my partner Remco, who was always willing to think along with me and supported me through the busy period of renovating our home. I would also like to thank my friends at TU Delft, who were always interested in my work and happy to help when I felt stuck.

Finally, thank you, reader, for taking the time to engage with my thesis. I hope you find it both insightful and inspiring.

Writing this thesis, I used ChatGPT to help rewrite and clarify my selfwritten texts. In addition, ChatGPT made some figures for context. All content is entirely my own work.

Warm Regards,
Iris Baart

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INTRODUCTION

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Urbanization and modern lifestyles have increasingly distanced people from the origins of their food (Xu et al., 2024). Many individuals no longer understand how vegetables are grown, how much care this process requires, or how seasonal cycles affect cultivation. This disconnection contributes to misconceptions about agriculture, poor dietary habits, and increased food waste (Rittgarn, 2023).

(Indoor) gardening offers a meaningful counterbalance. It promotes healthier eating, mental well-being, and social interaction, while also supporting sustainability by providing local produce (Avonts et al., 2023). Yet, despite its benefits, many novel gardeners face a steep learning curve. They often struggle with timing, watering, light intensity, and the right soil conditions. Indoors, limited space and inconsistent light make seed starting even more challenging, leading to weak growth and frustration.

This project is situated in the context of home gardening, focusing on novel vegetable gardeners who wish to learn to grow their own vegetables. Common situations include overcrowded windowsills and lack of knowledge (as stated above). These challenges highlight the need for a system that provides guidance and insight, not by taking control, but by helping users learn and build confidence.

The aim of this project is to design a smart, space-efficient growing system that assists novel gardeners in caring for their seedlings. Rather than prioritizing automation, the design focuses on education and empowers the users through clear, intuitive feedback. By combining smart technology with meaningful interaction, the design encourages learning by doing, helping users build confidence, understand plant care, and reconnect with the natural process of growing food.

In the following chapters, the design process is outlined, beginning with the research phase. The main goal of the research was to identify the key challenges faced by beginner gardeners, so the design could effectively address their needs. The research was conducted on two levels: human aspects of home gardening and plant-focused aspects. Based on these insights, conclusions were drawn to develop the design vision. From there, a list of requirements was established, and the initial concepts were created. The report then continues with concept development, iteration 1 and a detailed explanation of the final design. This is followed by validation, discussion, conclusion, recommendations, references, and finally, the appendix.

THE PROBLEM OWNER

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Simon Eurlings, also known as 'De Moestuinman' (The Vegetable Garden Man), is a young nature enthusiast from Heerlen who left his career in the commercial sector to follow his passion for greenery and sustainability. During the COVID-19 pandemic, he discovered how calming working with plants could be. A few broccoli seeds and an avocado pit marked the beginning of a new life direction, which developed into an active engagement with gardening and environmental education.

What started on his balcony quickly grew into a deep interest in gardening and the tranquility it provides. His nephews jokingly called him 'De Moestuinman', a name under which he began sharing his experiences on Instagram. Through his open, humorous, and approachable style, he has reached a wide audience and inspired others.
With his enthusiasm and down-to-earth approach, Simon encourages people to appreciate and actively engage with nature. He demonstrates that making mistakes is part of the process and emphasizes the enjoyment and experience of growing plants. His mission is to help people of all ages experience how happiness, growth, and calm can often be found literally in the soil.

Simon discovered that his followers have many questions about gardening. He also noticed that he has very little space on his windowsills for starting seeds. In response, he made a DIY solution using an IKEA cabinet, but it could still be more professional. Together with Simon, I, as a designer, am exploring how we can solve these two problems.
As a client, Simon provides an inspiring foundation for this project: his vision of accessible gardening and his desire to connect people with nature align perfectly with the design of a smart growing box that guides and motivates users in growing their own plants.

SIMON EURLINGS

HUMAN ASPECTS OF HOME GARDENING

This chapter explores the human aspects of home gardening. Literature research was conducted to understand how people learn most effectively and how they develop a connection with nature, as these are two essential considerations for the final design.

Further desk research examined current gardening practices and similar design solutions to identify where this project fits within that spectrum and what is still missing. To better understand the environments in which people live and the space available for the design, the human environment was explored, including housing types, windows, and indoor temperature. Additionally, research was conducted into indoor seed starting and optimal indoor conditions, to inform the design.

Finally, 3 interviews with experienced gardeners (experts) and a questionnaire among around 200 beginners were conducted to uncover their main challenges and needs.

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3.1 HOW DO PEOPLE LEARN?

Research has been conducted on how people learn most effectively. The goal of the final design is not only to transfer information, but also to make learning enjoyable, since indoor growing is often a hobby. The following section summarizes effective learning methods based on literature research, focusing on active engagement, learning through experience, and improving long-term retention while keeping the process motivating and accessible for users.

3.1.1 STRATEGIES FOR LONG-TERM RETENTION

Based on the meta-analysis, the most effective ways to learn are distributed practice and practice testing. Distributed practice means spreading study sessions over time instead of cramming, which helps long-term memory. Practice testing involves actively recalling information through quizzes or flashcards and works best with feedback to correct mistakes (Donoghue et al., 2021).

Although this technique is mainly discussed in the context of how information is best retained in school, it is generally important for learning that information is presented in a spaced manner. Presenting too much information at once can lead to forgetting. When information is spread out over time, it is easier to remember and is more likely to be stored in long-term memory. Repetition of information is also crucial for effective retention.

3.1.2 LEARNING THROUGH FAILURE

Education often focuses on avoiding mistakes, which can limit opportunities for deep learning. However, research shows that errors can play a crucial role in the learning process. When learners make mistakes and subsequently receive corrective feedback, their understanding is strengthened and information is more likely to be retained over time. This process encourages active engagement with the material, as learners are required to reflect on what went wrong and how to improve.
Learning through failure also supports the development of problem-solving skills and resilience. By encountering and overcoming challenges, learners become more comfortable with trial and error, which fosters a growth mindset and reduces fear of failure. Although incorporating mistakes into educational design can be challenging, it can lead to more meaningful and long-term learning outcomes. Embracing errors as part of the learning process therefore supports constructive and sustainable learning experiences (Mera, 2022).

3.1.3 LEARNING BY DOING

Learning by doing helps learners develop skills and understanding by actively taking part in the learning process. Instead of only focusing on learning new information, this approach also supports skills such as critical thinking, creativity, problem-solving, collaboration, and communication (Desrani, Ritonga, & Lubis, 2024).
By participating in hands-on activities, learners are encouraged to think about what they are doing, make choices, and reflect on the results of their actions. This active involvement keeps learners mentally engaged and helps them develop clearer and more structured ways of thinking, which makes learning more meaningful and long-lasting.
Learning also becomes more effective and motivating when ideas are applied in real-life situations. Seeing how concepts work in practice helps learners connect theory to real-world use. This not only improves understanding but also keeps learners engaged and helps them remember information for a longer time (Haraldsson et al., 2024). Combining hands-on activities with real-life applications therefore creates a strong and effective way of learning. This method differs from practice testing (as mentioned before) by actually doing it, instead of recalling information.

3.1.4 CONCLUSION

Learning by doing, learning through failure, and distributed practice all focus on active learner engagement rather than passive learning. They encourage learners to think, reflect, and interact with the learning material, which supports deeper understanding.
Learning by doing and learning through failure overlap in their emphasis on experience, as hands-on activities naturally involve making mistakes and learning from them through reflection and feedback. When gardening, every next year, there is another chance to improve and learn and improve over and over again (from mistakes). Distributed practice strengthens both methods by spreading learning over time, helping learners better retain knowledge and skills gained through practice and error.
Together, these methods create a coherent approach that supports meaningful, long-term learning.

3.1.5 MAIN TAKE-AWAYS

Next to each takeaway, a letter with a number is indicated (for example **R1**). This refers to the Requirement (**R**) or wish (**W**) associated with it. The list of requirements and wishes is described in Chapter 8.

Based on this information, it can be concluded that the design should take the following points into account:

- Learning by doing: People learn best through hands-on experience, and this should be reflected in the final design. There needs to be a balance between automation and activities that users can perform themselves. Smart features are helpful, but users should still have opportunities to actively engage in the process. So the final design should not be too automated. The user could be supported by some automated features, but will still need to do a lot themselves (**R12, *Active learning***).

- Learning through mistakes: It is not a problem if users make errors, even if immediate correction is not possible. The design will provide guidance and helpful tips, but not everything has to be perfect. It is important to note that the system should not intentionally cause users to make mistakes, as this can be demotivating. Since opportunities for retrying may only occur much later, users should be able to learn from initial attempts without relying on instant feedback. Users can still learn effectively from trial and error over time.

- Strategies for long-term retention: Information should be presented gradually. It is not necessary to provide all information at once. Distributing information over different periods helps users remember it better and supports long-term retention. This is often already the case when growing vegetables. Tasks are usually carried out step by step: first sowing, then transplanting, and eventually harvesting. This information is naturally distributed over time, making it ideal for applying the principle of distributed practice.

Figure 1: How do people learn?

3.2 CONNECTION WITH NATURE

To help restore the connection with nature, it is important to understand how people connect with the natural environment. What feelings do they experience, and what are the effects of spending time outdoors? This knowledge guides the design of gardening activities that strengthen people's connection to nature.This subchapter addresses these questions based on literature research.

People connect with nature through both emotional and psychological engagement and through mindful, attentive activities such as smelling flowers, observing birds, or walking. Indirect contact with nature, such as through books, media, or learning about natural environments, can also strengthen this connection. Importantly, it is not the amount of time spent in nature that matters, but meaningful moments of focused experience and attunement to the natural environment (Richardson et al., 2021).

Connection to nature is also influenced by personal affinity and familiarity with natural environments. Individuals with a strong sense of connectedness tend to engage more consciously and purposefully with nature, for example through walks or observing natural elements. This sense of connectedness enhances the mental benefits experienced, including reduced stress, anxiety, and depression, and can also provide cognitive benefits such as improved attention and focus. In contrast, people with a weaker connection to nature often experience fewer well-being benefits, even with frequent exposure (Chang et al., 2024).

Activities such as gardening promote healthier eating habits, social interaction, and mental well-being, even boosting serotonin levels in the brain for a mood-enhancing effect (Avonts et al., 2023).

3.3 INDOOR GARDENING

Although gardening mostly takes place outdoors, an equally important part occurs indoors, namely the preparation phase and sowing phase. Many people start seeds indoors or grow small plants such as herbs and leafy greens. To better understand this context, research was conducted into participants' living environments, including housing types, available indoor and outdoor space, and conditions such as windows, windowsills, and temperature. This paragraph also briefly explains the advantages of starting seeds indoors and the most important factors of growing seeds indoors.

3.3.1 WHY START SEEDS INDOORS?

Seed starting is a common practice that allows gardeners to control key conditions such as temperature, light, and moisture. Another reason is to start the season earlier, then only sowing outside.
By moving seed trays between indoors and outdoors depending on the weather, seedlings can develop into strong, healthy plants (Plukkers, 2025). However, not all crops require indoor sowing. Root vegetables like radishes and carrots, as well as spinach, generally perform better when sown directly outdoors due to their resilience and preference for cooler conditions (Plukkers, 2025).

3.3.2 OPTIMAL INDOOR CONDITIONS

For indoor seed starting, warmth and light are crucial and must be balanced for optimal growth (Plukkers, 2025). Average indoor temperatures are usually sufficient, but excessive heat without enough light can cause seedlings to become elongated and weak. Seedlings require approximately 12 to 16 hours of light per day (and when they are bigger 12-14 hours per day), which can be supplemented with grow lights if natural sunlight is insufficient. It is not about the strength of the light, but about the amount of time the lights are on. Imbalances, especially low light combined with high temperatures, lead to stretching, weaker roots, and increased susceptibility to disease.

3.3.3 AVERAGE INDOOR TEMPERATURE

According to the World Health Organization (WHO), an indoor temperature between 18˚C and 25˚C is recommended for residential buildings. Each room has a different temperature, the bedroom is often a few degrees cooler than the living room, while the bathroom is much warmer. Also per person the preference can be different due to health and level of activity. Despite these differences, a general guideline is that a temperature between 18˚C and 22˚C is considered comfortable for most residents (Edwards et al., 2025). This is a perfect temperature for seedlings to grow.

3.3.4 WINDOWS

As there is most light near a window (and thus a suitable place for seedlings), research was conducted on windows and windowsills. Understanding the amount of space available on and around windowsills in an average household is an important consideration for the design process.

Although it is difficult to determine the exact number of windows in a house, building regulations do set requirements for the amount of natural light in a space. According to the Dutch Besluit bouwwerken leefomgeving (Bbl), at least 10% of the floor area must consist of "equivalent daylight area," which corresponds to a minimum of 0.5 m² of equivalent daylight area per living space (Kenniscentrum Overheid, n.d.).

Using this guideline, it is possible to estimate the minimum number of windows a house should have. For instance, a 50 m² apartment must have a minimum equivalent daylight area of 5 m², which could be achieved with two medium-sized windows or three smaller ones. Similarly, a 25 m² living room requires at least 2.5 m² of equivalent daylight area, which can be provided by one large window or several smaller windows (Bosch, 2015).

The amount of light coming through these windows can vary significantly. This depends on the size of the window, as well as its orientation (north, east, south, or west). To gain a better understanding of this, further research was conducted using a questionnaire, which is discussed in more detail in Chapter 5.

3.3.5 WINDOWSILLS

The dimensions of windowsills vary considerably, as each house is different with its own characteristics. On average, the height of a windowsill ranges between 70 and 90 cm. The width is often the same as the width of the window, which can vary significantly from one house to another. The depth of the windowsill largely depends on its intended use. For instance, when designed to fit plants, windowsills are often made deeper to provide sufficient space. In contrast, windows in smaller areas may have shallower windowsills. In practice, the depth generally falls between 20 and 30 cm (Hundredworries, 2025).

3.3.6 APARTMENTS

Although a part of the target group lives in apartments or flats, this does not necessarily mean that people cannot engage in gardening. Some individuals have small balconies where they can grow vegetables and fruits on a limited scale, for example in pots. According to the results of the WoonOnderzoek Nederland 2021, at least 75% of people who rent privately (i.e., renting from a private landlord, such as an individual or a company, rather than a housing corporation) have a balcony or other outdoor space (Ministry of the Interior and Kingdom Relations, 2021).

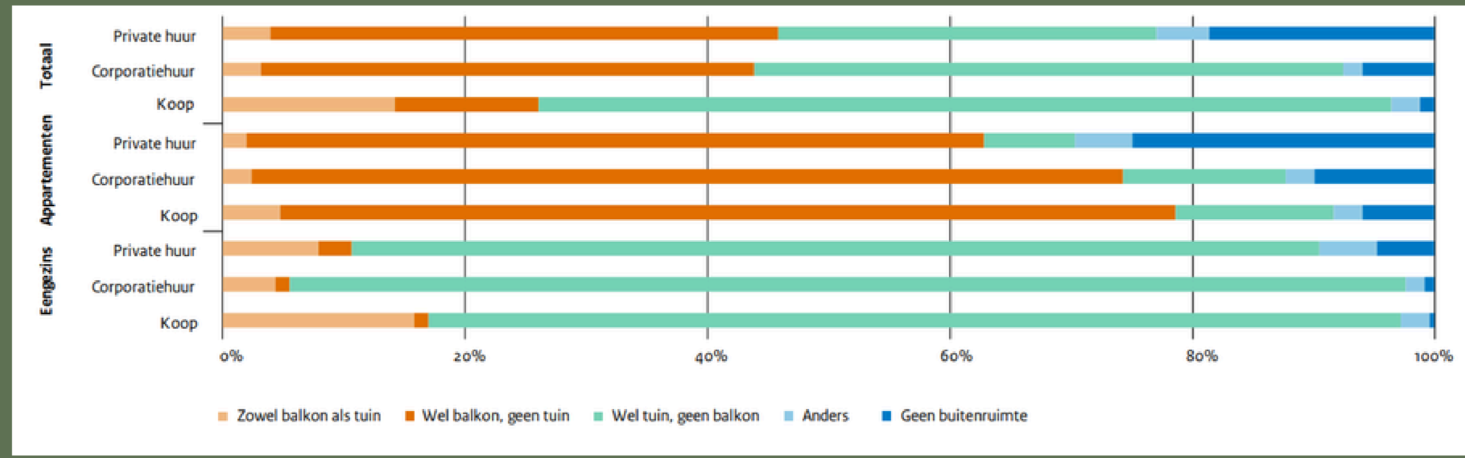


Figure 2: How many space do people have outside? (Ministry of the Interior and Kingdom Relations, 2021)

According to other sources, this number may be even higher. Bakker et al. (2022) report that over 80–90% of all households (i.e., across all types of dwellings) have some form of outdoor space, such as a garden, balcony, terrace, or other.

3.3.7 TYPE OF HOUSING

The target group, novel gardeners, lives in a wide variety of types of homes. Because it is such a broad group, there is no single type of home that they most commonly live in. Additionally, the difference between urban and rural areas can greatly influence the type of home and the amount of available land. Table 1 provides an overview of ages and the types of homes people live in.
The majority of households consist of adults aged 35 to 75, who mainly live in single-family homes. Young adults under 35 are more likely to live in multi-family homes, while seniors aged 75 and over still mostly reside in single-family homes, though the difference with multi-family homes is smaller. Overall, single-family homes remain the most common type of home.

Huishoudenskenmerken	2023* Totaal	Eengezinswoningen	Meergezinswoningen
	aantal		
Totaal	7 521 280	4 909 620	2 611 660
Leeftijd: jonger dan 35 jaar	1 207 945	501 120	706 820
Leeftijd: 35 tot 55 jaar	2 475 815	1 777 555	698 260
Leeftijd: 55 tot 75 jaar	2 664 405	1 939 885	724 520
Leeftijd: 75 jaar of ouder	1 173 115	691 060	482 060
Type: eenpersoonshuishouden	2 685 160	1 141 075	1 544 085
Type: eenoudergezin	573 040	383 515	189 525
Type: paar zonder kinderen	2 267 030	1 641 595	625 430
Type: paar met kind(eren)	1 959 495	1 727 465	232 030
Type: overige huishoudens	36 555	15 965	20 590
1e 20%-groep (laag inkomen)	.	.	.
2e 20%-groep	.	.	.
3e 20%-groep	.	.	.
4e 20%-groep	.	.	.
5e 20%-groep (hoog inkomen)	.	.	.
Inkomen onbekend	.	.	.

Bron: CBS

Table 1: Household characteristics(CBS, 2025)

3.3.8 MAIN TAKE-AWAYS

The research shows that people live in different environments, have varying amounts of space, and experience significant differences in indoor conditions. Several insights from this research are particularly relevant when developing a concept:

- **Modularity and compactness:** The system should fit on various windowsills and in different living spaces, ranging from small apartments to larger homes (***R5, Compact Design*** *and* ***W2, Usability/Several locations***).
- **Lighting:** Insufficient natural light can be supplemented with integrated grow lights or reflective surfaces (***R3, Manual adjustments***). It's not about the strength of the lights, but the amount of time the lights are on.
- **Safety and stability:** The system must be stable on windowsills and safe for indoor use (***R9, Sturdiness***).
- **Amount of space:** The amount of space available differs for every person or household. Nevertheless, there is always a possibility to get started, as everyone has some space where something can be grown. Whether this is on a large plot of land or on a balcony in pots does not matter.

It is important to take factors such as limited space and varying indoor conditions into account. The design must be suitable for use in any household.

3.4 GARDENING PRACTICES AND HABITS

To gain insight into current practices in vegetable gardening, research was conducted into existing trends. To provide context for the trends presented below, desk research was conducted using articles, reports, and online gardening sources. This research aimed to understand current practices and emerging developments within home gardening, including the methods, tools, and technologies that are commonly used or rapidly gaining popularity. It also examined how people obtain their food and which priorities, such as sustainability, convenience, or self-sufficiency, influence their gardening behaviour. Additionally, the research is categorized based on similarities in scale, context, purpose, and use of technology. This resulted in logical clusters such as indoor and technology-driven solutions, space-efficient gardening, sustainable practices, and collective gardening initiatives. While the findings cannot capture every possible development in this evolving field, they offer an accurate and representative overview of the key themes relevant today. An overview of the trends can be found in table 2.

3.4.1 TRENDS AND THEMES

Trend	Description	Location/ Application	Picture (s)
Indoor gardening & Smart systems	Growing herbs, leafy greens, hydroponics indoors; using LED lights, automation, IoT sensors, and smart gardening systems.	Houses, apartments, and urban settings where outdoor space is limited.	 *(Hill, 2025)*
Vertical gardening	Vertical racks, wall-mounted plants, vertical hydroponics to maximize small spaces.	Indoors (on walls, shelves, or alcoves) but also outdoors on balconies or building facades.	 *(Mijnverticaletuin, 2023)*

Table 2: Trends and themes

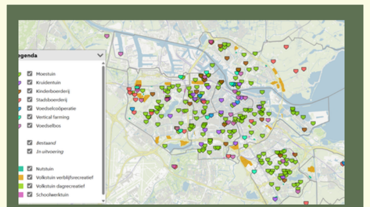
Trend	Description	Location/ Application	Picture (s)
Sustainability & Eco-Practices	Organic fertilizers, water-saving irrigation, compost, eco-friendly pots, material reuse; focus on environmental choices.	Both indoors and outdoors, with an emphasis on eco-friendly choices, for both hobbyists and serious growers.	 *(Tuinartikelen.nu, 2025)*
Urban/ community gardens	Increased participation in community gardens , mainly due to COVID-19 people encouraged outdoor hobbies and were searching for social interaction.	Primarily outdoors, in locations where multiple people come together to garden.	 *(Groen, 2025)*
Container/Pot gardening	Planting in pots; flexible for small spaces, not ideal for all crops but easy to manage	Outdoors or on balconies. This can even be done indoors as well.	 *(Kluiter, 2025)*
Community Picking Gardens	People can harvest their own vegetables and learn how crops are grown; a new form of shopping directly from gardens.	Happens outdoors. People who want to, can visit.	 *(Phoodfarm, n.d.)*
Community gardens	Nowadays, many larger cities have designated spaces, such as community gardens, where people can grow their own vegetables.	In most cases, you can register and rent a small plot of land for a fee in a lot of cities. However, if demand is high, there is a chance that you may be placed on a waiting list.	 *(Ebbers, n.d.)*

Table 2: Trends and themes

As shown in Table 2, gardening takes place both indoors and outdoors, depending on available space and personal preference. Indoor gardening mainly focuses on smart, vertical, and technology-supported systems, while outdoor gardening emphasizes social, educational, and ecological aspects through community gardens, community picking gardens, and balcony container gardening.

3.4.2 MAIN TAKE-AWAYS

For developing an indoor growing system, one insight is most important. For indoor use, it is important that the design is **compact and space-efficient.** This corresponds with requirement 5, and 6.

3.5 WHERE IN THE FIELD?

Desk research was also conducted using Pinterest and other online sources to explore existing approaches to home gardening, ranging from outdoor to indoor methods and from large-scale to small-scale setups. To gain an overview of the collected material, images were printed and cut out. These images were then grouped to bring some structure to the collection (see appendix 2). Based on this, two graphs were created to compare extremes: in Figure 3, the X-axis represents simple vs. complicated and the Y-axis represents limited vs. extensive growing possibilities. In Figure 4, the X-axis represents small vs. big and the Y-axis represents non-automated vs. automated systems. From these analyses, the positioning of the final concept within the field was determined (the white dot)

Figure 3: Field 1: Extensive growing possibilities vs Limited growing possibilities, simple vs complicated

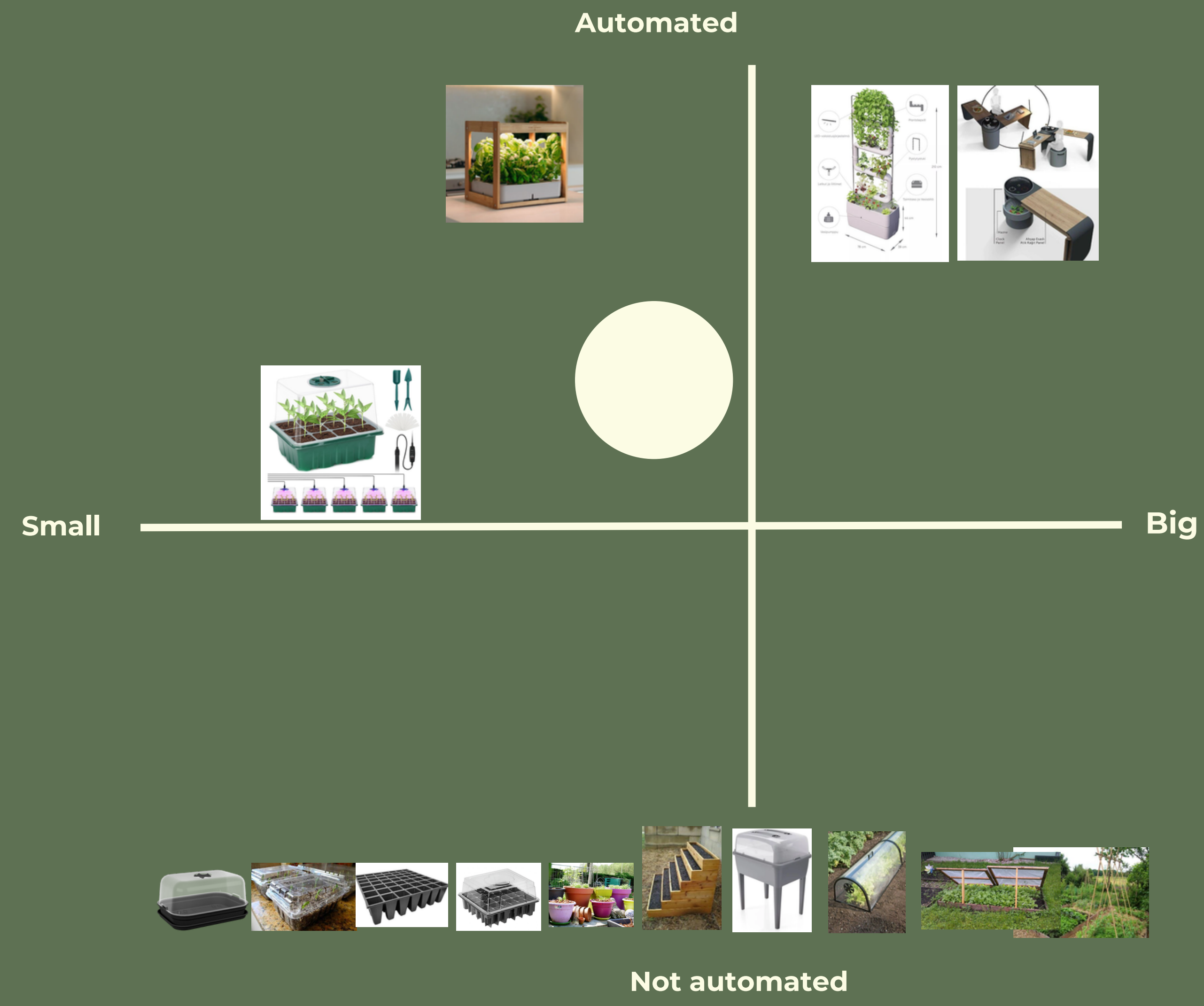


Figure 4: Field 2: Automated vs not automated, big vs small.

3.5.1 CONCLUSIONS

Based on the analysis presented in Figure 3 and 4, the design should not be too complicated so that beginner gardeners can easily understand it. However, due to the added smart features, the grow box will be slightly more complex than a fully 'simple' model. In the examples of the simplest designs, no additional guidance or support is provided. The final design, on the other hand, will offer extra support by growing vegetables. Is it important that the product will guide the user, but that it will not be fully automated.
At the same time, the design does not limit what can be grown. Since the box is specifically intended for seed starting, some crops like carrots and spinach are better sown directly in the soil, but otherwise the box offers a wide range of possibilities, from herbs and lettuce to other vegetable varieties.

Based on the analysis in Figure 4, the final design will remain relatively compact, allowing it to fit on a windowsill or elsewhere in the home. It would also be nice if it could be scaled up if desired, placing it between the size of a standard grow box and larger racks. Some features, such as the moisture sensor and potentially the lighting, will be automated, but the design emphasizes that users can perform most tasks themselves. This, to encourage learning and experimentation. The smart functions serve primarily as supportive tools rather than replacing hands-on interaction.

EXPERT INTERVIEWS

To gain a deeper understanding of the motivations, challenges, and learning processes of (novel) gardeners, three in-depth interviews were conducted with individuals at different experience levels: Gerda (30 years of experience), Erwin and Laura (14 years), and Simon (the problem owner) (5 years). Despite their differences in background and approach, several clear patterns emerged that provide valuable insights. The main data are summarized in the text below. All detailed questions and answers can be found in Appendix 3.

4.1 MOTIVATION AND BACKGROUND

All three participants started gardening for different reasons, but share similar intrinsic motivations: a desire for relaxation, connection with nature, and the satisfaction of growing their own food. They were introduced to it through family and the urge to try new things.

4.2 POSITIVE EXPERIENCES

For all participants, the harvest is the most rewarding moment; the tangible result of their efforts. They also enjoy experimenting with new plant varieties and learning through hands-on experience. Gardening offers them a sense of achievement and closeness to nature.

4.3 CHALLENGES AND FRUSTRATIONS

Despite their experience levels, the gardeners face similar challenges:

- **Timing and planning** (when and how to sow, water, or prune).
- **Limited space** and **pest** problems (slugs, mice).
- **Time** investment and maintenance, especially weeding.
- Disappointment when **crops fail** despite care and effort.

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4.4 LEARNING AND KNOWLEDGE DEVELOPMENT

All participants emphasized that they learn best through experience and interaction with others. Most of them learn from other gardeners but also books and online videos.

4.5 PRACTICAL APPROACH AND PREFERENCES

The gardeners favor plants that grow quickly and show visible progress, such as lettuce, tomatoes, herbs, and small fruits. They prefer flexible planning methods and intuitive experimentation over rigid schedules. Combinations such as beans, maize, and pumpkin (the “three sisters”) were mentioned as successful planting strategies.

4.6 TIPS FOR BEGINNERS

All participants emphasized the importance of starting small and keeping it enjoyable. They view mistakes as a natural and necessary part of the learning process. Success with simple crops builds confidence and encourages further experimentation.

4.7 MAIN TAKE-AWAYS

The interviews show that gardening is driven by experience, relaxation, and satisfaction rather than by productivity alone. Several insights from the interviews are particularly useful when developing a concept:

- **Clear, Practical Guidance:** Beginners need accessible, step-by-step instructions (***R8,*** *Practical Use*).
- **Visible Success & Motivation:** Small harvest moments or visible progress helps build motivation and confidence (**W3,** Visible Progress).
- **Support for Learning by Doing:** The design should encourage experimentation and discovery without strict rules, allowing beginners to make mistakes safely and learn from them (**R12,** Active Learning).
- **Positive Reinforcement & Enjoyment:** Focus on enjoyment, relaxation, and achievable successes rather than perfection; start small and let beginners grow what they like (to eat).
- **Success and Failure:** Failure is part of the gardening process. What succeeds one year may fail in another, and this is a natural part of gardening.

QUESTIONNAIRE NOVEL GARDENERS

05

A questionnaire was conducted among Simon's followers to gain insight into why people start (or have started) gardening, where they sow their seeds, and how much space they have available. Most importantly, it aimed to uncover the main challenges that beginning gardeners face. On average, there were 100 responses to the open-ended questions and 200 responses to the multiple-choice questions. Simon's followers are generally in the age group of 20 to 35 years, although there may be some outliers. They are all people interested in vegetable gardening and tips. This chapter presents the key findings, while the complete list of multiple-choice responses can be found in Appendix 4.

WHY DO PEOPLE GARDEN?

People garden mainly for relaxation and mental well-being, to grow healthy and tasty food, and to feel connected to nature and the process of growth. In addition, self-sufficiency, sustainability, and enjoyment or a sense of accomplishment play an important role. For many, gardening is also a way to teach children or spend time outdoors together.

WHERE DO PEOPLE TAKE THEIR SEEDLINGS?

Most respondents transfer their seedlings to their own garden, while a smaller group uses community gardens, balconies, or indoor spaces when outdoor space is limited .

WHERE DO PEOPLE SOW THEIR SEEDS?

Most respondents sow their seeds on a windowsill, while others use grow lights, a mix of methods, or greenhouses

HOW MANY SOUTH-FACING WINDOWS ARE AVAILABLE FOR SOWING?

Most respondents have one or two south-facing windows, while only a few have more or a greenhouse

IF YOU DON'T HAVE A GREENHOUSE, HOW MUCH SPACE DO YOU HAVE FOR INDOOR SOWING?

Most gardeners primarily use windowsills for sowing, with others using tables, shelves, or greenhouses. A smaller group has little or no suitable indoor space

WHAT CHALLENGES DID BEGINNERS FACE WHEN SOWING SEEDS?

Beginners often struggle with timing, overcrowding, insufficient light, high temperatures, and limited space, as well as pests and uncertainty about sowing and care (figure 5)

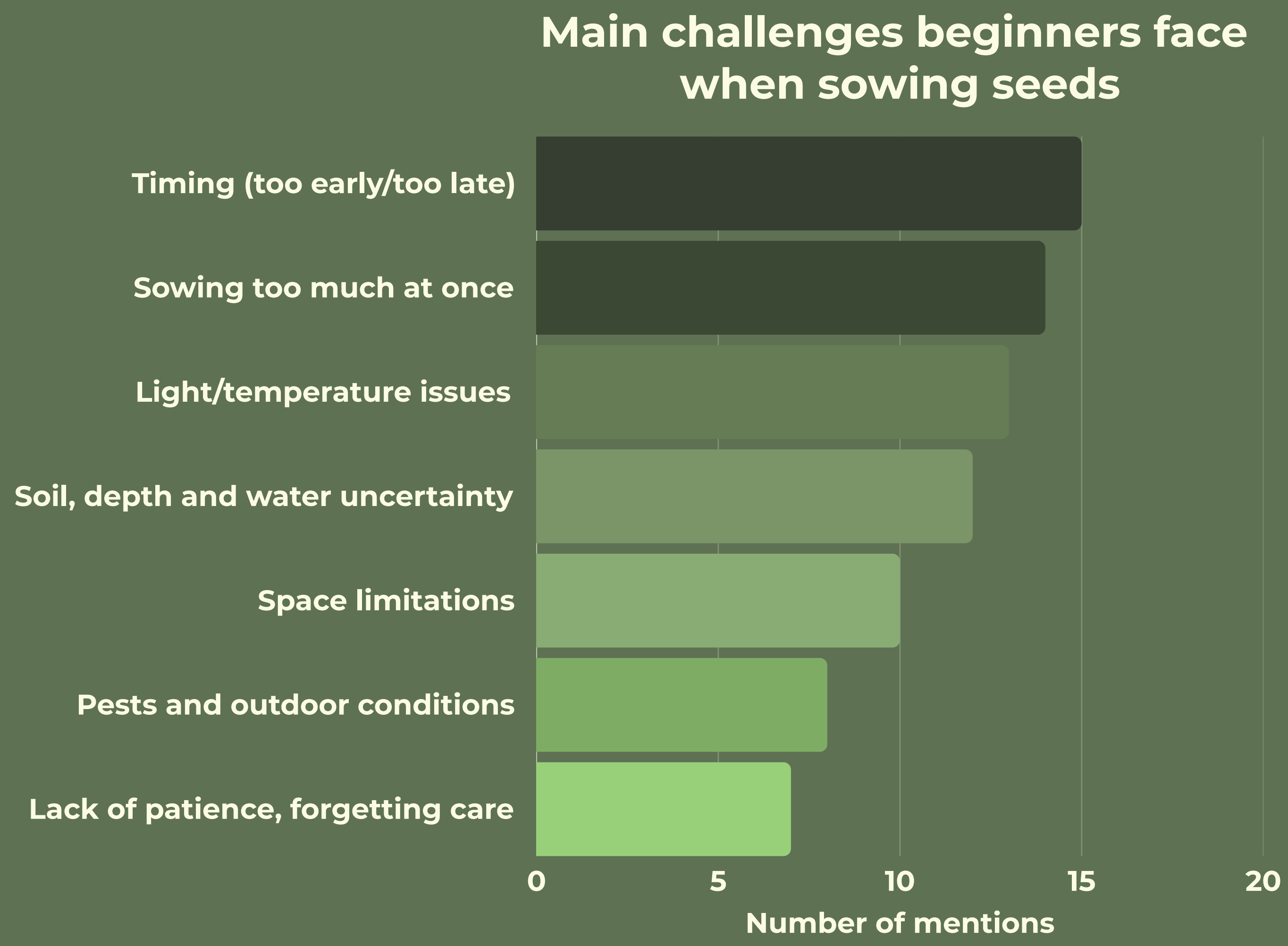


Figure 5: Main challenges beginners face when sowing seeds

5.1 CONCLUSION QUESTIONNAIRE

Both the survey and interviews show three main motivations for gardening:

- **Relaxation**
- **Mental peace**
- **Connecting to nature**

Most beginning gardeners start their seedlings indoors, often on the windowsill, due to limited space. Many have only one or two south-facing windows, meaning that light and space are scarce. Some find creative solutions such as using shelves or tables, but others clearly struggle with a lack of space.

Most of the problems take place in the beginning phase of growing plants: the sowing phase. The main challenges involve timing, space, and knowledge. Beginners often sow too early or too late, too many seeds at once, or too close together. They also face issues with insufficient light, high indoor temperatures, and uncertainty about soil type, watering, and transplanting.

5.2 MAIN TAKE-AWAYS

When designing a solution for novel gardeners, it is essential to:

1. Take **limited space** and **light** as a starting point: consider compact, space-efficient, or modular solutions (**R3**, Manual adjustments, ***R5,*** *Compact Design and* ***R6,*** *Space efficiency*).

2. Provide **ease of use** and **guidance**. Show it when the user has to do something: for example, through clear instructions, visual aids, or smart timing tips (***R7,*** *Simplicity & Intuitiveness and* ***R8,*** *Practical Use*)

3. **Encourage** motivation and **enjoyment:** since relaxation and satisfaction are major drivers (***W3,*** *Visible Progress*).

4. Offer **support** with planning and moderation: to help beginners know when, how much, and how to sow (***R1,*** *Seed planting guidance and* ***R2,*** *Water monitoring).*

As also highlighted in the conclusion of this chapter, most problems occur in the early stages of growing plants—the sowing phase. Because many challenges arise at this stage, focusing the design on seed starting indoors is a strong starting point. Addressing problems during sowing and germination will help beginner gardeners get off to a good start and tackle the most common struggles.

Figure 6,7 : AI-generated context pictures

PLANTS

06

This chapter focuses on how to create optimal conditions for plant growth. It explores what plants need, such as light, nutrients, water, and soil types, and how these needs can be actively managed. Through desk and literature research, methods for regulating and supporting plant growth have been identified, including the use of water sensors, grow lamps, and strategies to prevent pests and diseases. This knowledge highlights which aspects can be automated or controlled and which are essential to monitor, providing a foundation for designing a system that ensures seedlings can grow as effectively as possible.

6.1 PHOTOSYNTHESIS

A plant needs very different elements to grow: water, (sun)light, and CO2. Plants obtain energy from sunlight. This energy is converted into oxygen and glucose by chloroplasts, water, and CO2. The plant uses this glucose as food and can therefore largely grow. This process, in which light energy is converted into chemical energy, is called photosynthesis (Wageningen University, 2020), (Gaiseanu, 2022). The process is also shown in figure 8.

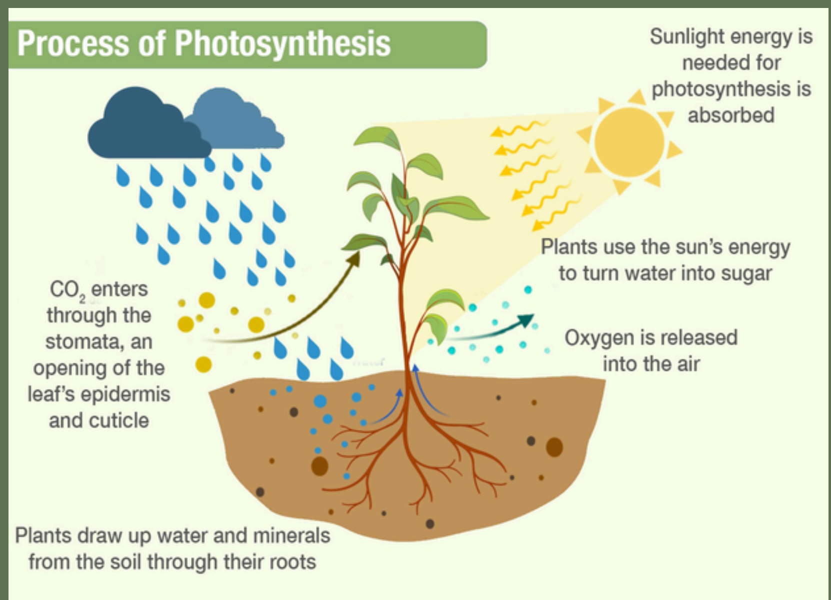


Figure 8: Process of photosynthesis (Gaiseanu, 2022)

6.2 NUTRIENTS

Plants require water, (sun)light, and essential nutrients to grow. Nutrients are absorbed through roots and are divided into macronutrients (needed in large amounts) and micronutrients (needed in trace amounts). (Zewide, 2021),(Johnson, 2020). These are shown in Table 3.

Macronutrients: vital for structural growth, photosynthesis, and protein formation	Micronutrients: regulate enzyme activity and chlorophyll synthesis
Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), and Sulfur (S).	Iron (Fe), Zinc (Zn), Copper (Cu), Manganese (Mn), Boron (B), Molybdenum (Mo), and Nickel (Ni).

Table 3: Macronutrients and Micronutrients

6.2.1 SOIL

In a natural environment, plants get their nutrients out of soil. Soil is a living ecosystem composed of organic matter, minerals, water, air, and countless organisms including bacteria, fungi, nematodes, and earthworms. Healthy soil supports plant growth by providing nutrients, water retention, aeration, and a balanced environment for (micro)organisms. An overview of the living organisms in the soil is shown in the Soil Food Web in figure 9. There are different soil types which have distinct characteristics, shown in table 4 at the next page (Augustijns, 2014; Koomen, 2025)

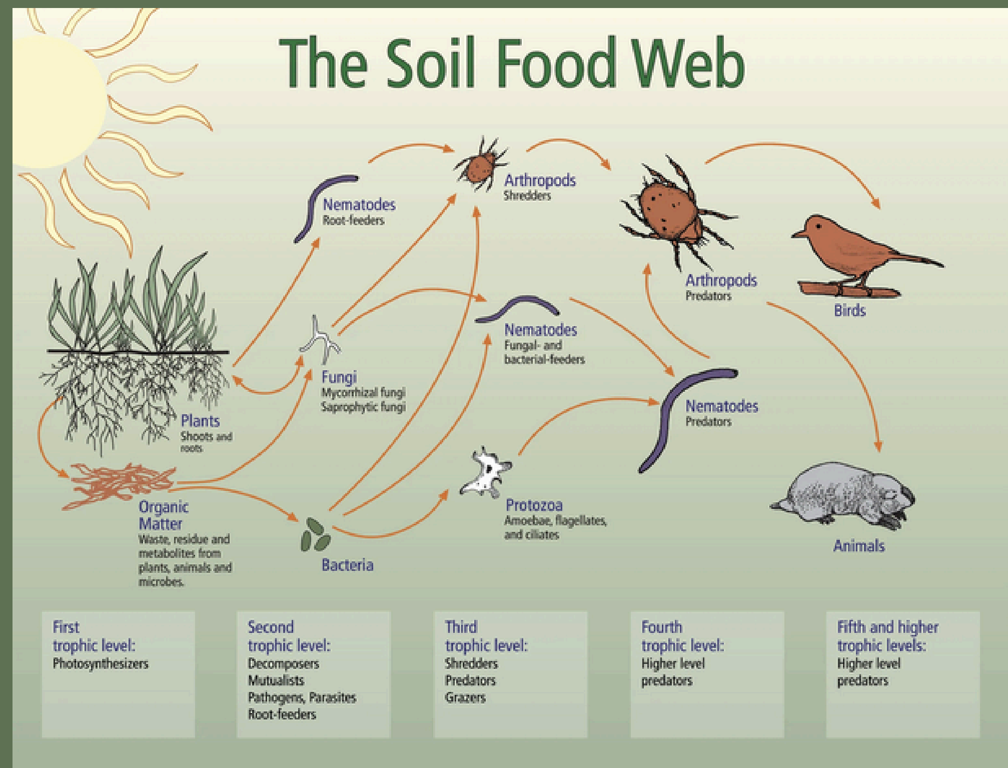


Figure 9: The food soil web (bodemwereld, 2023).

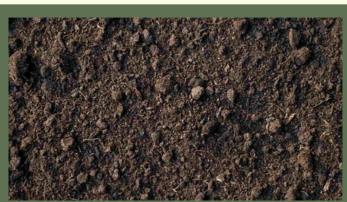
Type of soil		Characteristics
Clay Soil		Heavy, compact, and firm soil that retains nutrients and water well but can be difficult for roots to penetrate if low in organic matter (Maslen, 2025).
Sandy Soil		Light-colored, loose soil with a well-drained structure that does not retain water or nutrients well (Nielsen, 2024).
Silty Soil		Yellow-brown soil, finer and more compact than sand, retaining moisture while remaining well-drained and rich in organic matter (Lawnseeds, 2025).
Loam Soil		Balanced mixture of clay, sand, and silt, retaining both moisture and nutrients efficiently (Dirt connections, 2021).

Table 4: Types of soil

6.3 LIGHT

Light is a key factor for photosynthesis, plant growth, pigmentation, flowering, and overall plant health. Plants rely on the photosynthetically active radiation (PAR) spectrum (400–700 nm), where blue light (~450 nm) promotes compact growth and strong leaves, and red light (~660 nm) encourages flowering and fruiting. Each color has a different impact on plants, which is shown in figure 10 (Liu et al., 2021).

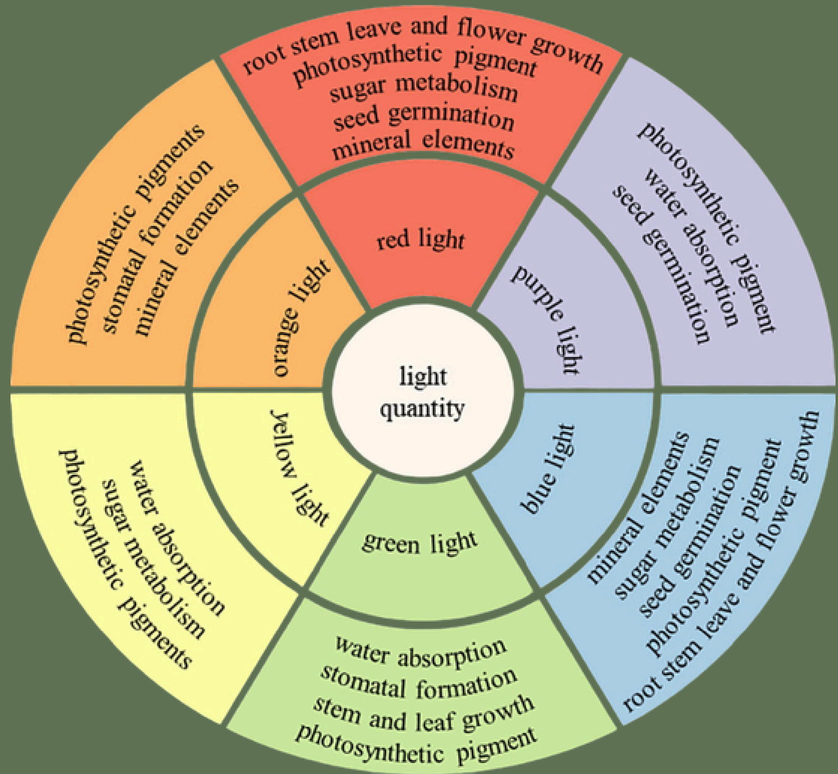


Figure 10: The role of different light qualities on plants (Wu et al., 2025).

When sunlight is insufficient, artificial lighting supports plant growth. Common types include fluorescent, HPS, MH, and increasingly LEDs, which are energy-efficient, low-heat, and allow tailored light spectra (Americanbright, 2024). Modern systems use innovations like diffusers, multi-channel modules, and solar spectral shaping to ensure even light distribution, improve growth, and even help manage pests and diseases (Neo, 2022).

Optimal growth depends on balancing light intensity and duration. The light compensation point (LCP) is the intensity at which photosynthesis equals respiration; extending the duration of light rather than increasing intensity can improve growth without harming plants (Li et al., 2025). This can also be taken into account creating a design.

Figure 11: Led strip (amazon, n.d.)

For artificial lighting, LED grow lights are preferred for small setups because they are energy-efficient, produce low heat, allow spectrum customization, and have a long lifespan, unlike fluorescent or high-intensity discharge lamps which have limitations in efficiency, heat, and size.

For optimal seedling growth, it is important that they receive enough light, as they need between 12 and 16 hours of light per day. When starting seeds (sometimes as early as February), this amount of light is simply not yet available. In addition, not everyone has the space to place seedlings in a very sunny spot. For these reasons, this factor will definitely be taken into account in the final design.

6.4 MOISTURE SENSORS

A review of existing moisture sensors was conducted to determine suitable options for a smart grow box. Details are shown below, with the full study in Appendix 5.

For indoor seedling growth, maintaining optimal soil moisture is essential. Capacitive sensors are most suitable for small grow boxes due to their accuracy and durability, with ideal moisture levels around 25–35% VWC during germination and 20–30% during the seedling stage.

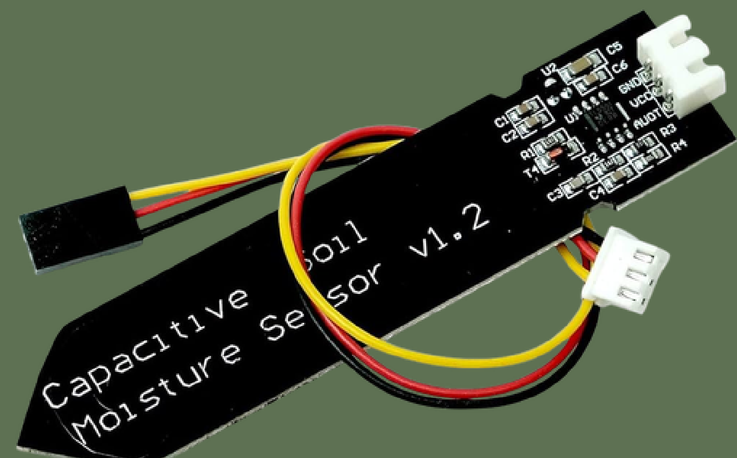


Figure 12: Capacitive soil moisture sensor (amazon, n.d.)

6.5 DISEASES AND PEST MANAGEMENT

Plants can be affected by various diseases and pests, including fungi, bacteria, viruses, nematodes, and mites, shown in table 5.

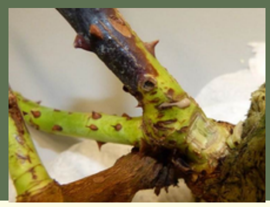
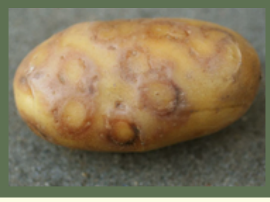
Type	Symptoms/effects
Fungi 	Cause wilting, leaf or stem rot, and gray mold (Hudelson, 2024).
Bacteria 	Leads to spots, rot, and leaf wilting (NVWA, 2025).
Viruses 	Can result in stunted growth and reduced crop quality (Schadbild, 2025).
Nematodes 	Can damage roots (NVWA, 2024).
Mites 	Suck sap from leaves, weakening the plant (NVWA, 2024).

Table 5: various diseases and pests explained

Indoor growing environments often pose extra challenges due to warm, humid, and poorly ventilated conditions, which can promote pests and diseases. The most significant threats to young plants are aphids, whiteflies, and fern weevils, as they can slow growth or weaken seedlings. To prevent these problems, early detection is crucial. Simple measures, such as proper ventilation, controlled humidity, and correct watering, can greatly reduce the risk. Additionally, treatments like rinsing leaves with water or introducing natural predators (e.g., ladybugs, lacewings, or parasitic wasps) can help manage infestations if they occur.

6.6 MAIN TAKE-AWAYS

From this plant-focused research, several points can be applied to the final design:

1. **Light**: Light is essential for the optimal growth of seedlings. Since seedlings need between 12 and 16 hours of light, a light source is highly desirable in the final design. It does not need to have high intensity, but it is better to provide a longer light duration to avoid damaging the plants (***R3,*** *Manual adjustments*).
2. **Humidity**: Use capacitive sensors for accurate moisture measurement; 25–35% VWC during germination, 20–30% during the seedling stage. To better support the user, it would be nice if a moisture sensor is added, to help watering (***R2,*** *Water Monitoring).* The humidity is not only important for the plants themselves, but also for fungi to develop (too wet will cause rots).
3. **Nutrients & Soil**: Use potting soil or compost-rich soil; replenish nutrients regularly to maintain optimal levels *(**R1**, seed planting).*
4. **Pests & Diseases**: Ensure good air circulation, inspect plants early, and use natural predators where possible.
5. **Growing System**: Hydroponic or soil-based systems are practical for small containers; vertical or modular setups save space (***R5,*** *Compact design and* ***R6,*** *Space Efficiency*).
6. **Automation**: Sensors and grow lights improve success and make maintenance easier; controlling the microclimate is crucial. Therefore, a combination of these are desirable for the design *(**R2,** Water Monitoring and **R3,** Manual adjustments).*

MAIN CONCLUSIONS RESEARCH

07

In this chapter, the main findings of the research will be presented. Based on this research, several important conclusions have been drawn that are essential to the design process. For the next stages, a number of aspects are of particular importance, namely: how people learn, how people establish a connection with nature and what the main challenges are for a novice gardener. These are (together with the main take-aways) linked to the requirements which can be found in the next chapter.

7.1 LEARNING PROCESS

There are various ways in which individuals acquire knowledge. Primarily, people learn through hands-on experience and by making mistakes, from which valuable insights are gained *(**R12**, active learning).* Furthermore, it is important to distribute information over time rather than presenting it all at once, as this supports better retention and understanding. When gardening, everything happens step by step anyway, because of all the different steps you go through from seed to fruit (first sowing, repotting, planting outside, etc.)

7.2 CONNECTING WITH NATURE

Individuals establish a connection with nature in different ways. Some engage in activities such as walking or running, while others appreciate the natural environment through sensory experiences, such as smelling and listening. What matters is not the duration of this interaction, but the quality of the moments experienced *(**W4**, connection nature).* This connection to nature offers numerous mental and physical benefits, contributing to reduced stress levels and, ultimately, improved concentration.

7.3 MAIN CHALLENGES

During the questionnaire, several problems experienced by novice gardeners were identified. These issues primarily arise during the sowing stage. The seven most significant challenges are illustrated in Figure 13:

1. First, it is difficult to know when to start sowing. As a result, this often goes wrong because people begin sowing either too early or too late *(**R1**, seed planting).*
2. People also tend to sow too much at once. Too many seeds are placed in seed trays, leaving them with insufficient space to grow. In addition, people often sow more than they can ultimately plant out, resulting in a large number of seedlings that are unlikely to survive *(**R1**, seed planting).*
3. The conditions for pre-sowing can also be challenging. Since pre-sowing usually takes place indoors, the balance between light and temperature is not always optimal. While indoor environments are often relatively warm, this is not always compensated for by sufficient light *(**R3**, manual adjustments).*
4. Watering remains particularly difficult for beginners. Questions such as "How much water should I give?" and "When should I water?" are common. In addition, people often forget to water the seedlings *(**R2**, water monitoring).*
5. It is also difficult to know exactly what is needed when sowing seeds. This usually starts with selecting suitable soil and determining how deep the seeds should be planted *(**R1**, seed planting).*
6. Overall, caring for plants is challenging. Beginners often struggle to understand what plants truly need and which steps must be followed to successfully grow from seed to harvest.
7. Finally, space is a major challenge. Windowsills quickly become overcrowded with seedlings, leaving very little remaining space. Moreover, not everyone has a large windowsill on which to place their seedlings *(**R5**, compact design), (**R6**, space efficiency).*

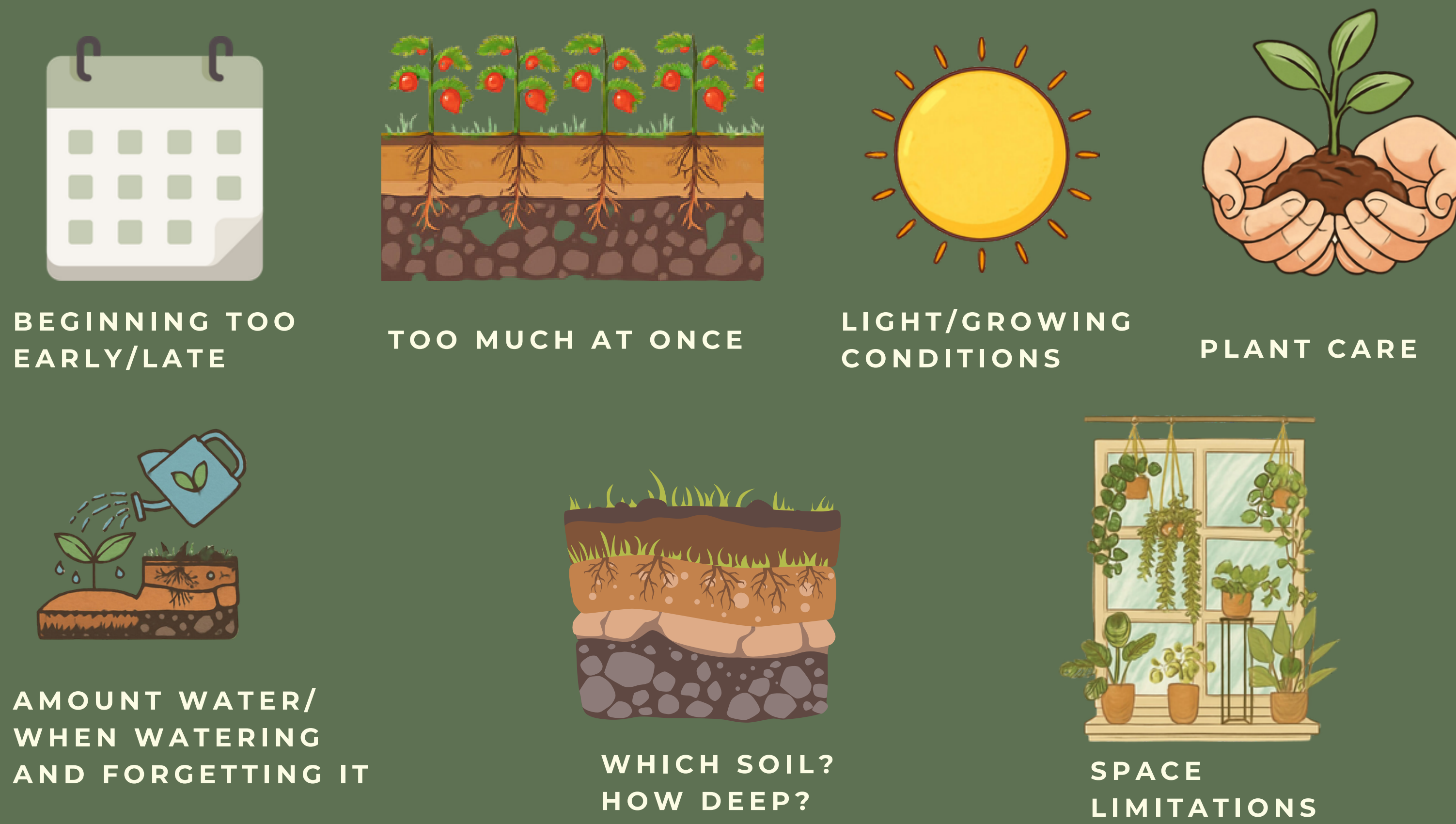


Figure 13: Most significant challenges

LIST OF REQUIREMENTS AND WISHES

08

Based on the research take-aways, a list of requirements and wishes has been established that the design must/can meet. These lists are primarily based on the conclusions drawn from the research described above. In table 6, the list of requirements can be found and in table 7, the wishes can be found.

Requirement	Explanation
R1 Seed planting guidance	The product shall provide clear step-by-step guidance for seed planting, including depth and spacing.
R2 Water monitoring	The system shall monitor soil moisture and give feedback to the user when values fall outside the optimal range for seedlings.
R3 Manual adjustments	The user shall be able to manually refill water and adjust lighting (not everything should be automated).
R4 Plant variety	The system shall support a wide variety of plant categories. These will overarch the easiest plants to start with, where success is guaranteed.
R5 Compact design	The product shall fit on a desk, shelf or windowsill.
R6 Space Efficiency	The product shall optimize planting capacity in limited indoor spaces by enabling vertical or modular use.
R7 Simplicity & Intuitiveness	A first-time user shall be able to start easily, using only the provided instructions.

Table 6: List of Requirements

Requirement	Explanation
R8 Practical Use	The product must be practical and convenient to use in everyday situations. Its use and required actions should be clear to the user at all times, ensuring that plant care can be carried out easily and without confusion.
R9 Sturdiness	The structure must safely support the expected load of plants, soil, and water, including a safety margin to account for growth and watering, without permanent deformation or loss of stability.
R10 Reusable	The product shall be designed for long-term indoor use, with structural components maintaining their function and stability under normal use conditions without requiring replacement.
R11 Storage	The product shall be able to be disassembled or folded to a storage volume reduced by at least 50%.
R12 Active Learning	The product should stimulate the user to learn actively.

Wishes	Explanation
W1 Notifications	Alerts when attention is needed, e.g. too dry or too wet.
W2 Usability/ several locations	It would be useful if the user could choose where to use the product: on the windowsill, on the table, or somewhere else in the house.
W3 Visible progress	It should be nice if the user will get visible progress by using the product. Showing the progress that you made helps building motivation and confidence.
W4 Connection with nature	It would be nice if people get connected to nature (again) in some way by the design.
W5 Adjustability	It would be useful if the design is adjustable to the size of the plants, so that they have space for the entire pre-sowing phase (around 30cm high, depends on the plants).
W6 Aesthetics	It would be nice if the product, besides being easy to use, also looks nice. After all, it has to be in someone's (living) room.

Table 7: List of Wishes

THE DESIGN VISION

Based on the seven main challenges, explained in chapter 7, two design directions emerged: lack of knowledge and space limitations. As these design directions can be effectively combined, a clear design vision was formulated that will serve as input to the conceptualization phase. Figure 14 shows where the words in the sentence originate from. These can be traced back to the research mentioned above.

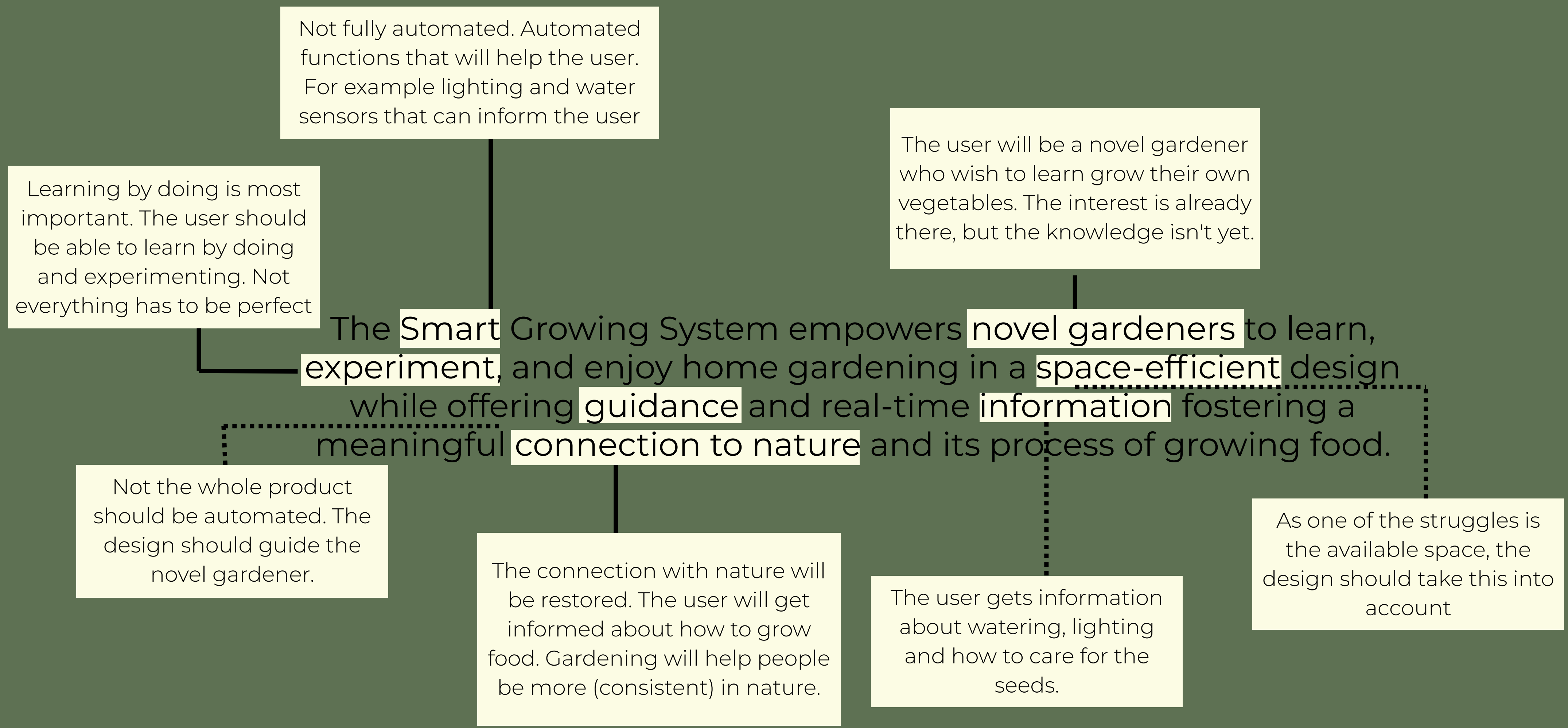


Figure 14: Design vision

9.1 WHAT VALUE DOES THE PRODUCT PROVIDE ON AN INDIVIDUAL LEVEL?

The smart growing system gives users the opportunity to actively learn gardening, rather than relying entirely on automation. It provides support during the first steps of planting and caring for seeds, while allowing experimentation, mistakes, and discovery of how plants grow. Users have the freedom to choose which plants to grow, from herbs and leafy greens to other varieties, offering plenty of room for creativity. Its compact, space-efficient design makes it suitable for almost any home, and the ergonomic, clear layout makes it easy and enjoyable to use. In this way, it combines the convenience of a smart growing system with the freedom, learning experience, and enjoyment of traditional gardening.

9.2 THE OVERARCHING GOAL OF THE DESIGN

This smart growing system does more than support individual learning; it encourages a deeper connection between people and the natural world. By making gardening accessible and engaging, it allows users to learn more about the food they eat, how it is grown, and to enjoy the benefits of fresh, healthy produce. This promotes not only a more responsible and thoughtful approach to food use, but also a healthier lifestyle, while raising awareness of sustainable practices and natural cycles. The design supports experimentation and curiosity, helping people appreciate the process of nurturing life and making mindful, health-conscious choices. In this way, the system adds value not only to personal growth but also to a broader understanding of sustainability, well-being, and living in harmony with nature.

DESIGN PROCESS

In order to develop the final design, several methods were employed to generate ideas and gain a broader understanding of what is possible. For idea generation a variety of techniques are used, namely a co-design session with fellow students, How-To guides, and a morphological chart. These brainstorming activities produced three concept ideas. To select which idea to develop further, a Harris profile was used. This chapter explains each method step by step and presents the attendant conclusions.

10.1 HOW TO'S

In the early phase of the design process, there were still many questions as a designer about what was possible. In the "How To's," you ask yourself as a designer the question: *How to solve problem X?* Then, you write down as many possible solutions as you can to solve the given problem or answer the given question. In Figure 15, you can see one of the brainstorming sessions on adding growing lamps to the design. The remaining How To's can be found in Appendix 6.

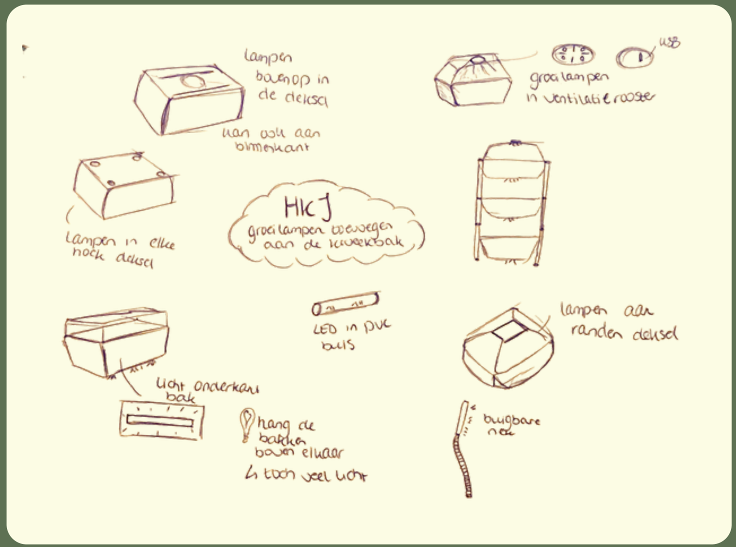


Figure 15: How to: Add growing lamps to your concept?

10.2 CO- DESIGN SESSION

To explore innovative designs, a collaborative brainstorming session was conducted with class mates. Because they did not know a lot about the topic, this could result in different (out of the box) ideas, that i did not think of yet. This offered a new perspective on the design.

10.2.1 OBJECTIVE

The primary goal of the session was to explore the two design directions: Lack of knowledge and space limitations. This, to generate potential solutions for both directions without restrictions.

10

10.2.2 METHOD

The session was structured around two design questions:

1. **In what ways can knowledge be transferred?**
2. **How can the space for a grow box be used efficiently?**

These were explained verbally to four classmates. The group was then divided into two so no one had to wait and the ideas would be less influenced by one another. Each classmate was given 3 minutes to come up with ideas for both design directions. After everyone had drawn or written down their ideas, each one was explained in detail. This ensured that the ideas were clear to everyone and allowed for further brainstorming afterward.

Figure 16: Co-design session

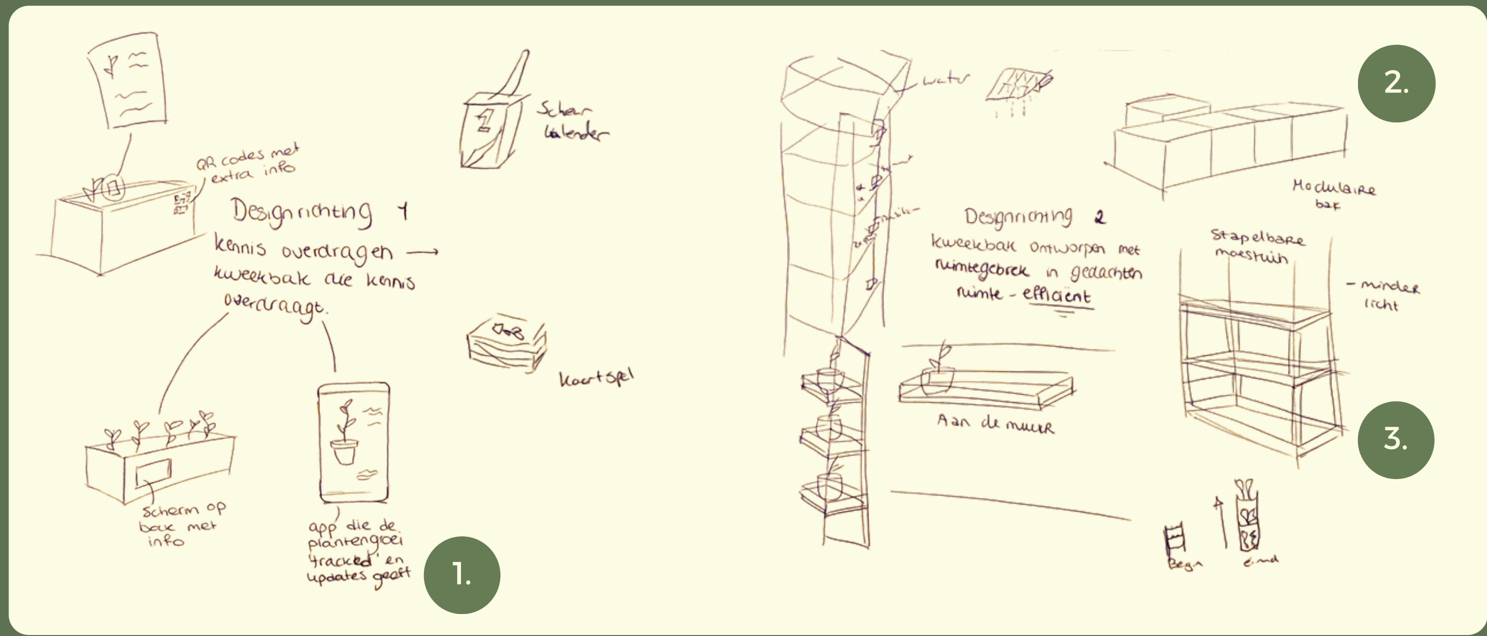


Figure 17: Outcomes co design session

From this brainstorming session, the most promising ideas were selected together with my classmates. These are shown with numbers in Figure 17. These are the ideas that we believed had the most potential, based on the program of requirements and wishes.

10.3 MORPHOLOGICAL CHART

To organize all the ideas and simultaneously explore unanswered questions, a morphological chart was created. I used the chart as a flexible tool for overview and brainstorming, rather than strictly following the classic sub-function–solution model. This allowed me to quickly gather ideas, explore possible combinations, and creatively connect them, making it a practical tool for my design process. As a result, it provided a comprehensive overview of all ideas for further concept development. The colors are divided according to different parts of the concept: yellow indicates elements useful for the app, blue highlights aspects I want to see reflected in the physical design, and other colors were used to indicate possible combinations (Figure 18). Only a part is shown, the rest can be found in appendix 7.

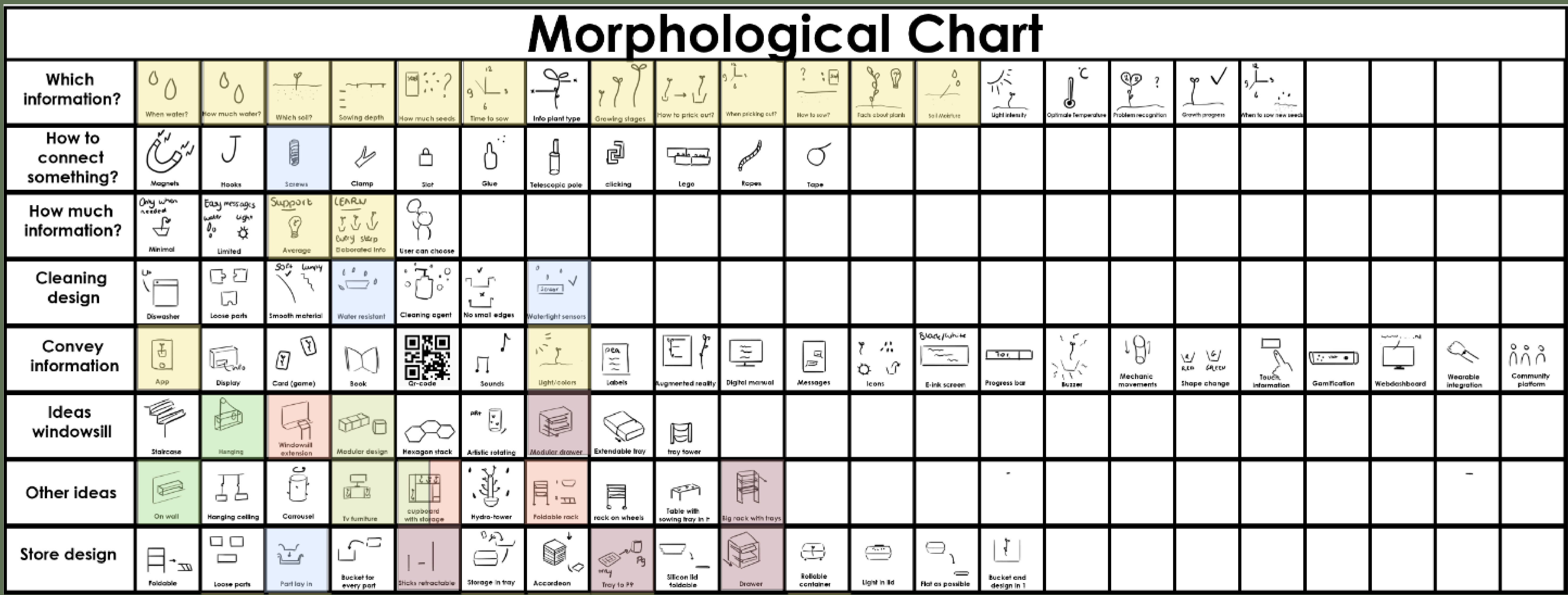


Figure 18: Morphological Chart

CONCEPTS

11

After applying these methods, a selection of the most valuable ideas was made ,taking the preference of Simon in account. These ideas were further developed into concepts. The final concept will be combined with the two design directions: space efficiency and information transfer. The concepts presented in this chapter belong to the space-efficiency design direction (not yet the smart functions integrated).
After several brainstorming sessions, the decision was made to transfer information through an app; this will be explained further in Chapter 11.4.1.

11.1 CONCEPT 1: WINDOWSILL EXTENSION

Concept 1 is called: the Windowsill Extension. As the name suggests, this growing system is designed as an extension of the windowsill. According to the questionnaire conducted among novice gardeners, it became clear that people generally have limited space on their windowsills for placing seed trays. With this concept, the growing tray can be pulled outward, thereby creating twice as much usable space (***R6,*** *space efficiency*). The tray is additionally reinforced by support legs that fold out underneath the box, including anti-slip feet (***R8***, *Practical use*). Moreover, this concept makes efficient use of the natural light that already enters through the window (***R7***, *Simplicity & Intuitivity*). There is also no height restriction, so any crop could grow in it (**R4** ,Plant variety). To identify a suitable sliding mechanism, a short brainstorming session was conducted on possible mechanisms (see Appendix 8). Eventually, one of these mechanisms was tested using a small 3D-printed prototype. Figure 19 illustrates a technical drawing of the working principle of the concept.

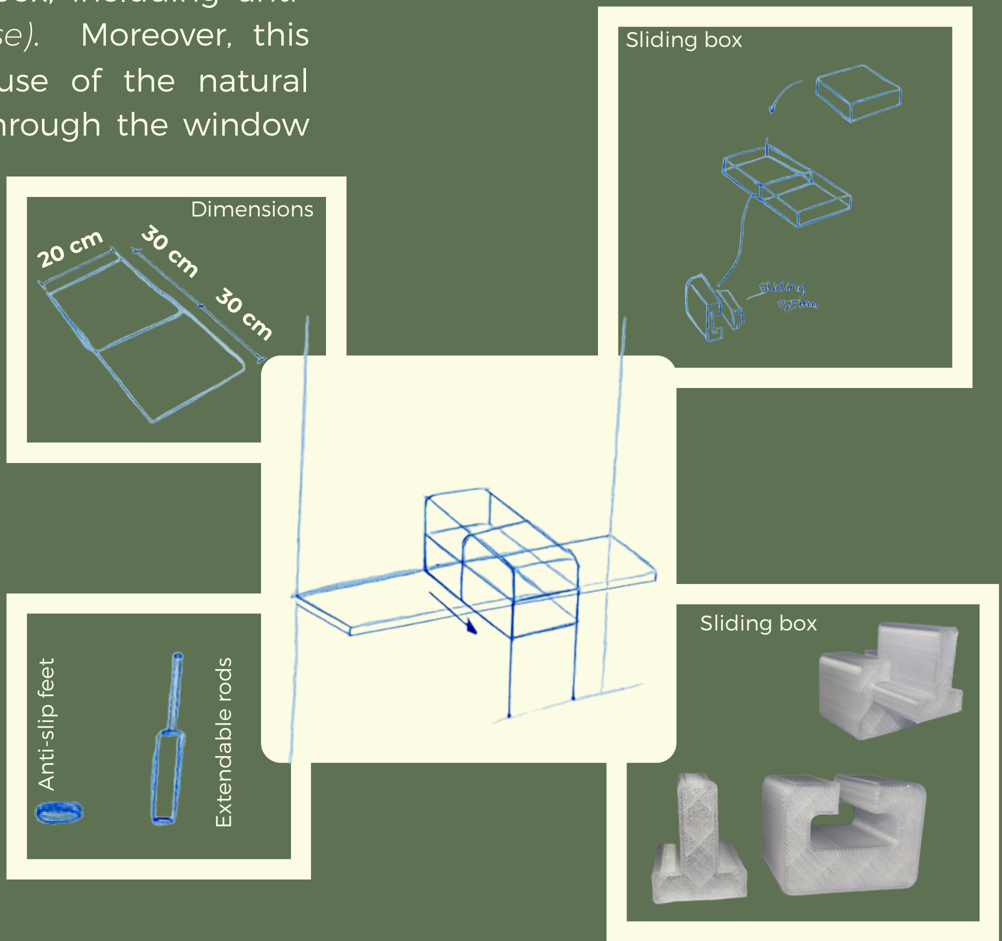


Figure 19: Concept 1, windowsill extension

11.2 CONCEPT 2: MODULAR STACKING

Modular Stacking is a concept made up of multiple components that can be expanded based on the user's needs. The foundation is a growing box with a base and a transparent lid. This box can be placed on a windowsill and makes use of the natural light coming from outside (***R7***, *Simplicity & Intuitivity*). Both the base and the lid contain magnets in the corners, allowing additional boxes to be added and stacked as desired (***R5***, *compact design*, ***R6***, *Space efficiency*). The ventilation slider provides extra airflow after germination. Modular Stacking is suited for gardeners who want to sow just a little or a lot, its size and configuration can be fully adapted to the user's preferences (***W5***, *adjustability*).

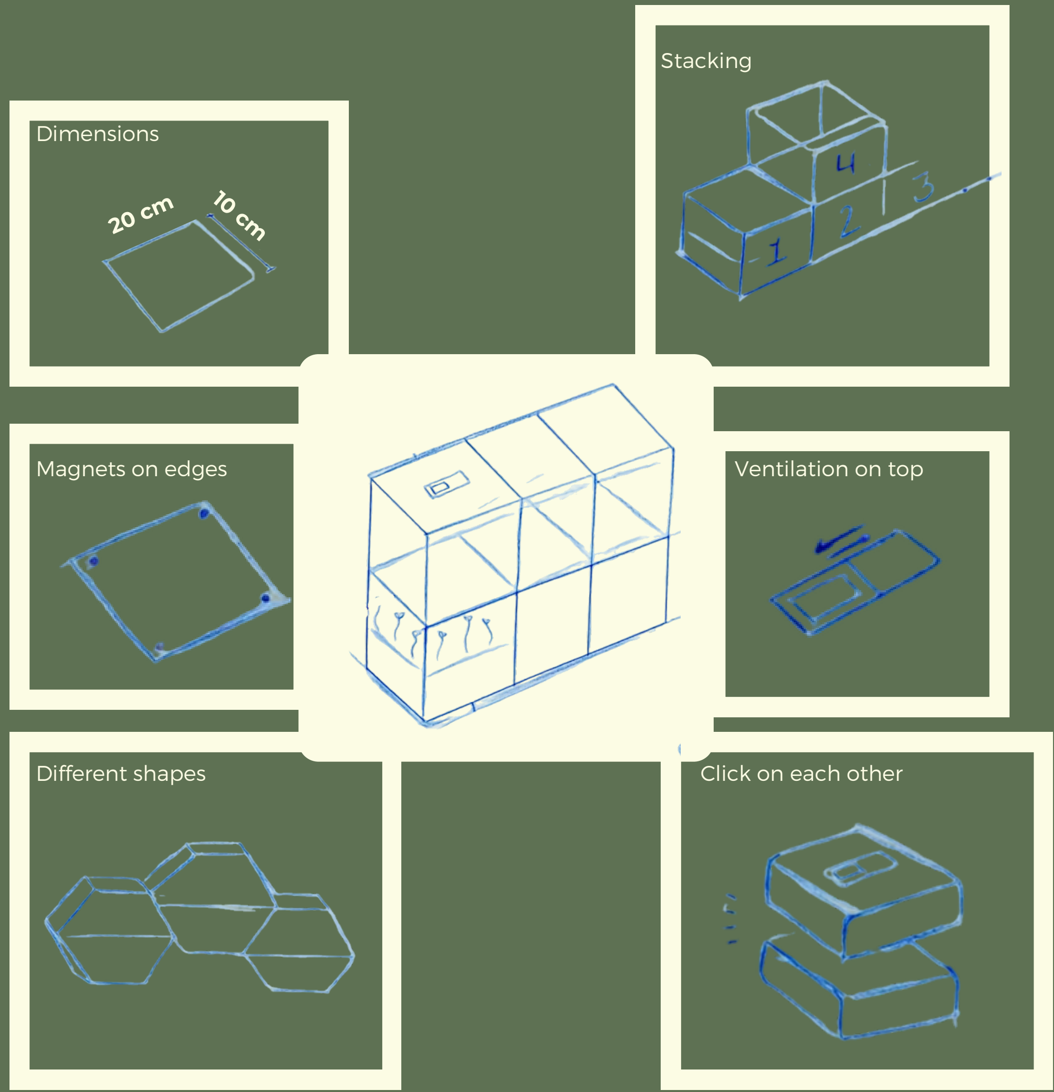


Figure 20: Concept 2, Modular stacking

11.3 CONCEPT 3: MODULAR DRAWER

The third concept is the Modular Drawer. This idea works like a drawer in which growing trays can slide into a frame. The tray includes basic features such as LED lighting for healthy growth and simple ventilation (***R7***, *simplicity and intuitiveness)*. As the seedlings grow, the lid can be flipped and used as a bottom support, keeping the components neatly organized during use (***R5***, *compact design).*

The tray can be filled with either small compartments or P9 pots, making it suitable for both germination and further plant development (***R4***, *plant variety).* The possibility of using both a sowing tray and a P9 pot, was a wish of De Moestuinman. Finally, multiple trays can be stacked in a frame, which is height-adjustable so the system can grow along with the plants (***W5***, *adjustability).*

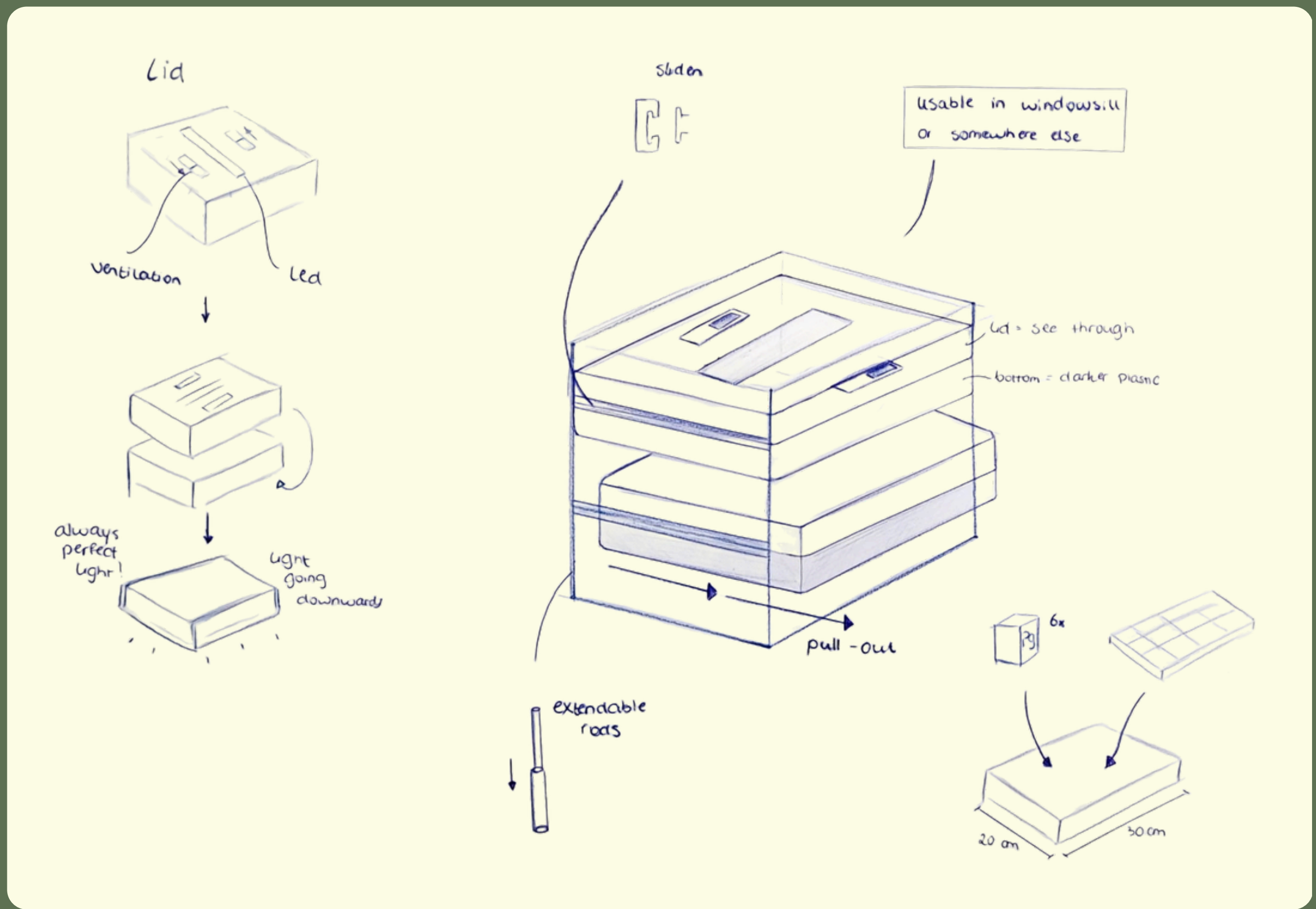


Figure 21: Concept 3, Modular drawer

11.4 CONCEPT SELECTION

This chapter further elaborates on the selection of the chosen concept. The decisions made during the design process are explained in more detail. Since the concept combines two design directions, these choices will be discussed separately.

11.4.1 DESIGN VISION INFORMATION TRANSFERRING

The design choice was made based on the list of requirements and in consultation with Simon. During this discussion, we concluded that an app is the most suitable solution for information transfer. An app is user-friendly, clearly readable, and always within reach.

Figure 22: App development

Compared to the other ideas mentioned in appendix 9, an app offers functionality and flexibility without additional hardware costs. Almost everyone already owns a smartphone, and the app can be easily installed and updated. This allows for clear, step-by-step instructions, while keeping costs low and ensuring an optimal user experience.

Besides, engaging with gardening, in this way strengthens your connection with nature (**W4**, connection nature). Besides being fun, you learn something new about the wonders of nature every time (***R12***, *Active learning*).

Finally, an app can easily be updated. If things change or if information needs to be adjusted based on weather conditions, it can be updated at any time. This is more difficult with a book, which is fixed at the moment it is printed.

11.4.2 DESIGN VISION SPACE EFFICIENCY

To select one of the concepts from the space-efficiency design direction, a Harris Profile was used to visually compare the strengths and weaknesses of the three different concepts against a set of criteria.

The requirements for the physical design (as previously described in Chapter X) were listed, compared, and ranked according to these criteria (see Table 8). As the information will be transfered via an app, R1 and R12 are ranked the same, as this will be determined by the use of the app.

	Concept 1: Windowsill Extension				Concept 2: Modular Stacking				Concept 3: Modular Drawer			
Requirement	-2	-1	+1	+2	-2	-1	+1	+2	-2	-1	+1	+2
R1 Seed planting guidance			■	■			■	■			■	■
R2 Water monitoring			■	■			■	■			■	■
R3 Manual adjustments			■	■			■				■	■
R4 Plant variety			■			■					■	
R5 Compact design			■				■	■			■	
R6 Space Efficiency			■	■			■	■			■	■
R7 Simplicity & Intuitiveness			■	■			■				■	■
R8 Practical Use			■			■					■	■
R9 Sturdiness		■				■					■	■
R10 Reusable			■	■			■	■			■	■
R11 Storage			■				■	■			■	
R12 Active learning			■	■			■	■			■	■
Total				18				13				21

Table 8: Harris Profile

From this comparison, it becomes clear that Concept 3: the Modular Drawer concept scores the highest.
Compared to concepts 1 and 2, Concept 3 scores significantly better on practical use and sturdiness. The sliding legs of the windowsill extension, in particular, make it less stable than Concept 3, which has a solid base. Therefore, this concept will be further developed.

CONCEPT DEVELOPMENT

This chapter will show the steps taken from concept to iteration 1. For the design, it is important that the different components work well together. The growing tray itself still needs to be further developed and must be able to slide easily into the frame. In addition, several iterations and tests have been carried out with the structure of the app. In this chapter, more will be explained about designing the growing box, iterations and user tests.

12.1 NEW VS EXISTING TRAY

Before discussing the iterations of designing a new growing tray, it is important to explain why I, as a designer, chose to develop a completely new growing tray, despite the many options already available. Although the modular option of using an existing tray offered lower costs and broader compatibility, designing a frame to fit various trays would have required extra adjustability, making the design more complex and limiting control, consistency, and user experience.

A custom tray allows full control over lighting, ventilation, and moisture, ensuring all components work seamlessly together *(**R2**, Water monitoring, **R3** Manual adjustments)*. This results in more reliable measurements and predictable growing conditions. Usability for beginners is also improved, as a single integrated system provides a clear workflow, reducing uncertainty and lowering the learning barrier *(**W2**, Usability)*.

Furthermore, a complete system enhances innovation and aesthetic consistency *(**W6**, Aesthetics)*, allowing the tray, frame, and app to form one coherent product. While a new tray involves higher production costs and slightly lower material reuse, the benefits in functionality, reliability, learning support, and user experience outweigh these drawbacks. The custom growing tray therefore best supports the project's goal of providing an accessible, reliable, and educational growing system for beginners.

12.2 ITERATIONS GROWING TRAY

The design of the growing tray did not need to be too complicated. A base, a lid, and an inlay are sufficient to allow seedlings to grow larger. Several iterations were made in the design, mainly focusing on ease of use. A design was created in SolidWorks (see Appendix 10) and then 3D printed at a 1:2 scale. This allowed all components to be properly tested.

12

Several iterations were made for the tray itself: the white/transparent 3D print is the first print, and the black print is an iteration based on it:

1. First, the lid: in the initial developed concepts, lighting was integrated into the lid itself. In the second concept, the mounting was simplified by adding a continuous channel for the LED light. In a later iteration, the light was integrated into the frame instead of the lid. The shape and size of the ventilation hole were also changed to make it more practical to use (**R8**, practical use). In the first design, the ventilation slide could not be properly fixed to the lid and did not slide smoothly. In the following iteration, this issue was resolved by adjusting the shape and the mounting system.

Figure 23: Lid iterations

2. Second, the bottom: In the bottom, it is important that any excess water has a place to go. As stated in the research, one challenge for a novel gardeners is watering (this can be too little, but also too much). In the first design, this consisted of small round indentations, but during testing with a large amount of excess water, these did not provide enough space. In the second iteration, more space was created using long channels. Additionally, in the first iteration, the inlay did not fit properly into the bottom. It was therefore made slightly wider so that it could slide in easily.

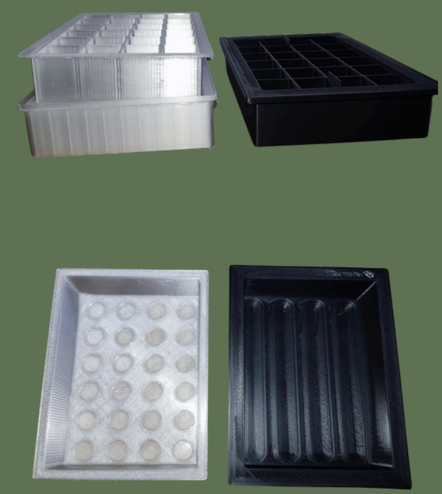


Figure 24: Bottom iterations

3. Third, the inlay: An inlay has been made so that a variety of crops can be planted (**R4**, plant variety), without being mixed up. The different compartments make it easier to get specific seedlings out of the tray. The inlay met expectations fairly early on. After a user test, feedback was given to add something that would make it easier to remove the inlay from the bottom. When the compartments are filled with soil, you have to dig in with your fingers, which is inconvenient. Therefore, two surfaces were added to allow the inlay to be lifted more easily (see Figure 25).

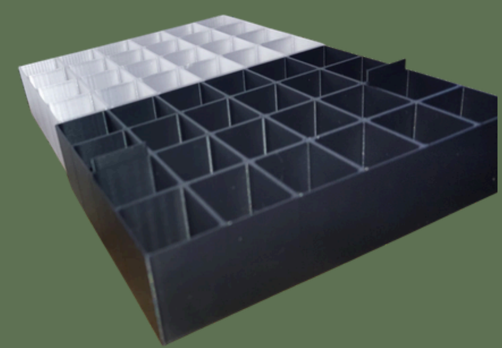


Figure 25: Inlay iterations

12.3 VENTILATION SLIDES

Six iterations of the ventilation slide were printed. The slide needed to click securely into the lid, which required the connecting piece to fit perfectly. Because this required precise work, quite a few iterations were needed (left are the first iterations, right the last iterations).

Figure 26: Ventilation slides iterations

12.4 SLIDE MECHANISMS

In addition, the tray itself needs to slide smoothly into the frame. Various dimensions and methods were tested for this (see Figure 27). Ultimately, I found that an angled rail would also be a good and more cost-effective option for the final design. These rails are sturdy, and the tray rests securely on them. In addition, they allow for more tolerance when sliding the growing tray into place.

Figure 27: Slide Mechanisms iterations

12.5 APP

During the different iterations of the app, changes were made to the wording and layout to improve clarity and usability (**R8**, practical use). In addition, feedback from user testing led to the inclusion of several new ideas and features within the app.

Before ***After***

Figure 28: Iterations app

12.6 PROTOTYPE FRAME

To test the frame, a prototype was built using steel tubes and wooden beams. This prototype was mainly intended to test the mechanism, gather user feedback, and evaluate whether it functions as intended. The prototype can be seen in the image below.

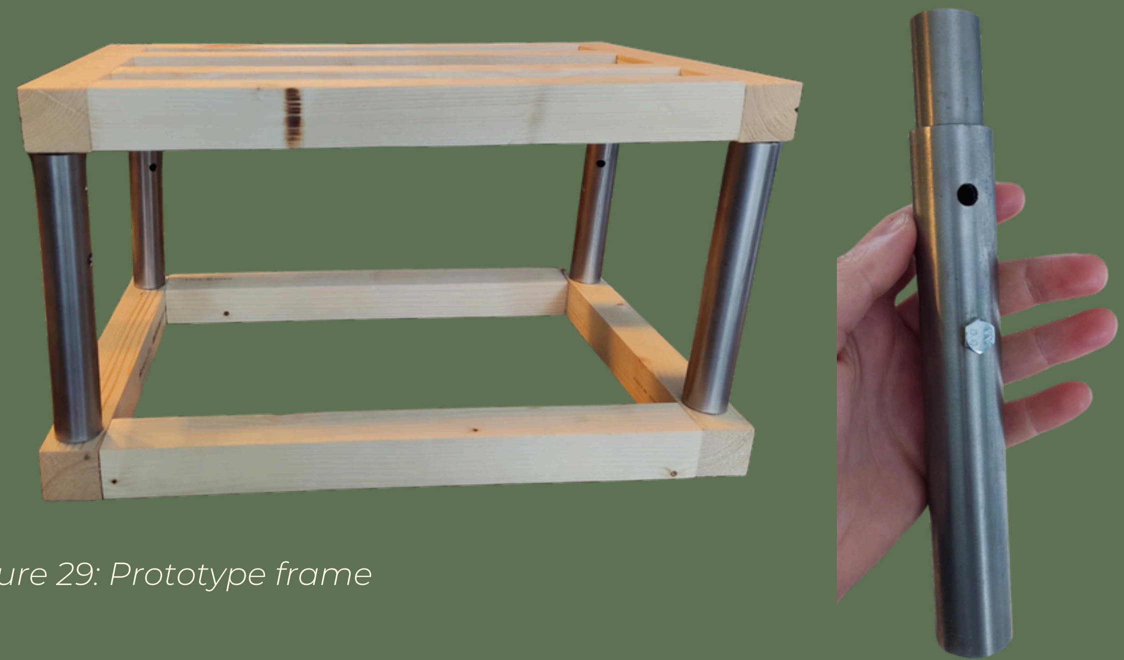


Figure 29: Prototype frame

12.7 PROTOTYPE GROWING TRAY

To see if everything works well together, the growing tray was 3D printed. This gave me, as a designer, good insight into what works and what doesn't. So far, everything in the growing tray fits together very well, and all the components seem to work well together. However, we still need to see how connecting the moisture sensor and placing the tray in the frame will actually work. The functionality, such as the inlay, the holes in the bottom, and the surfaces on the bottom where water can slide in, will also need to be tested later. For now, this is a very positive step.

Figure 30: Prototype growing tray

ITERATION 1

13

The main parts of iteration 1 consists of the frame, the growing tray, and the app. Together, with the moisture sensor and led lights, these form the complete design. Every smaller components will be explained step by step in this chapter. In figure 31, the desing for iteration one can be found in context.

Figure 31: Design iteration 1

13.1 FRAME

The frame consists of several components: the wooden beams, adjustable tubes with push buttons, LED lighting, and an angle profile on which the growing tray can be slid. These components will be explained individually in this sub-chapter.

13.1.1 WOODEN FRAME

The base of the frame consists of wooden beams measuring 2 by 2 cm. These dimensions look still clean, but create also enough strength to the design *(**W6**, Aesthetics, **R9** ,Sturdiness).* The overall frame is approximately 36 cm wide and 27 cm long. The most important function of these beams is to provide support and stability for the entire structure. The frame must be able to carry the weight of the growing trays and, if the user wants to save additional space, an extra frame can be attached on top of it, using bolts *(**R6**, Space efficiency).*

The frame consists of two parts: a bottom section and a top section. The top section contains two additional beams to which the LED strips can be attached, allowing the seedlings to grow optimally. By adding light, the user can put the system everywhere, as there is no dependency on light from the windows *(**W2**, Usability).*The use of wood gives the entire frame a warm, natural, and sustainable appearance *(**W4**, Connection with nature).* In addition, the beams have rounded edges for an elegant look, and the wood will be stained to enhance its visual appeal even further.

13.1.2 ALUMINIUM RODS

Most of the structural strength is provided by the extendable rods, connected with screws. These rods are made of aluminium, ensuring that the frame remains lightweight while still being strong and stable *(**R9**, Sturdiness).* In addition to providing structural support, the rods also serve an adjustable function, allowing the height of the frame to be modified *(**W5**, Adjustability).*

Figure 32: Designed frame with and without growing tray.

One rod consists of three components:

- Two thicker outer tubes with a diameter of 15 mm and a wall thickness of 2 mm. Each tube is 17 cm long and contains one adjustment hole.
- One thinner inner tube with a diameter of 8 mm and a wall thickness of 1 mm. This tube is 27 cm long and contains 6 holes, allowing the two thicker tubes to be positioned at three different height settings. In this way, the frame could be adjusted per growing stage.

The thin inner tube slides into the two thicker outer tubes and can move up and down by pressing the spring button clips. In this way, the rods allow each "level" of the frame to be adjusted to three different height positions, which helps the growth of the plants over time. The maximum height each level can reach is 30 cm, which corresponds approximately to the height of a fully grown seedling (in a P9 pot).

Figure 33: Leg button clip (Fruugo, n.d.)

13.1.3 CORNER LINE

The growing tray can easily be slid into the frame using an angle profile. This angle profile provides a simple yet efficient support on which the growing tray can rest securely. The profiles are fixed at a set position on the aluminium rods, ensuring that they remain at the same height when the rods are adjusted. They are made of aluminium, which provides sufficient strength while visually matching the rest of the design.

Figure 34: Corner line (Metaalshopper, n.d.)

13.1.4 LED STRIPS

Pre-sowing can be challenging, especially at the beginning of the year. Seedlings can quickly become long and thin because the balance between heat and light is often not optimal. To restore this balance and support healthy growth, LED strips have been integrated into the design. The LED strips ensure that seedlings receive between 12 and 16 hours of light during the germination phase. LEDs consume very little energy, making it acceptable for them to remain on for long periods throughout the day. In addition, LEDs are relatively inexpensive and energy-efficient, which makes them an ideal addition to the frame. The LEDs are powered through a low-voltage system using an off-the-shelf 5V or 12V adapter. This reduces safety risks associated with mains electricity and makes the system safer for indoor use. The leds will be glued to the frame and bottom for optimal light for both sowing trays.

13.2 GROWING TRAY

The growing tray consists of several components, including the lid, the base, and the inlay, combined with lighting and a moisture sensor. These will be explained more in detail in this chapter, including dimensions. The numbers correspond with the right information.

13.2.1 BOTTOM 1

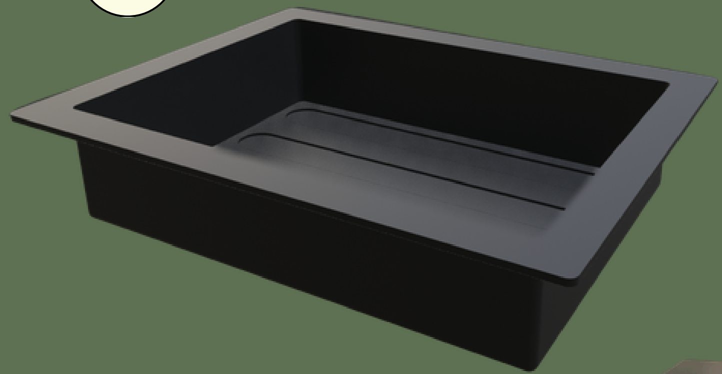
The base of the growing tray is a relatively simple design. It is rectangular in shape, allowing the lid to fit perfectly on top. The protruding edges are used to slide the entire tray into the frame. Indentations have been made in the base itself to collect any excess water, preventing it from remaining in the soil around the plants up to a certain level. In addition, magnets are in a specific part of the bottom so the moisture sensor can be put on. Finally, a LED strip can be attached to the underside of the base to provide additional light for the tray below.

13.2.2 LID 2

The transparent lid of the growing tray fits perfectly onto the bottom, resting over the bulging edges. It is made transparent so that sunlight can easily pass through. The lid also contains ventilation holes where the ventilation slide can be mounted. The ventilation slide can be clicked into the lid and moved back and forth. When the seedlings require less humidity (usually after germination), the slide can be opened to increase airflow.

Once the seedlings have grown taller and reach the lid, the lid can be placed upside down beneath the base. This provides a convenient storage solution when the lid is no longer needed (***R11***, *Storage)*. The LED strip that was previously attached to the base can then be mounted on the inverted lid. In addition, the lid is also provided of magnets to put the moisture sensor on.

1



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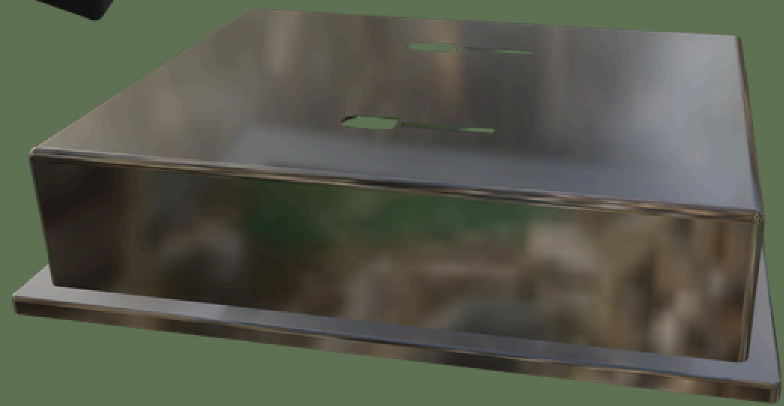

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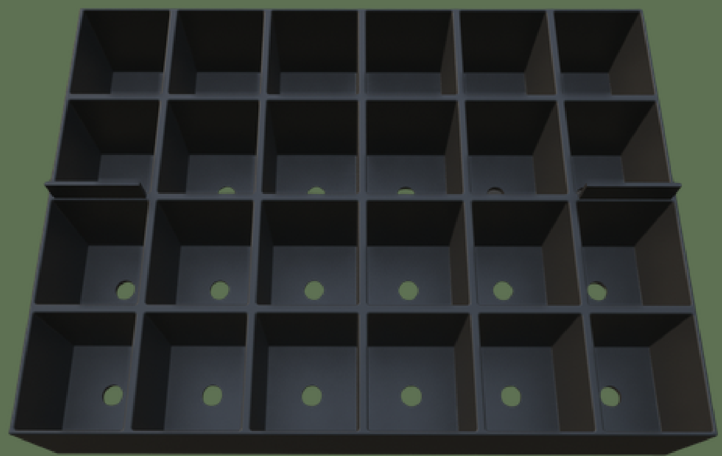
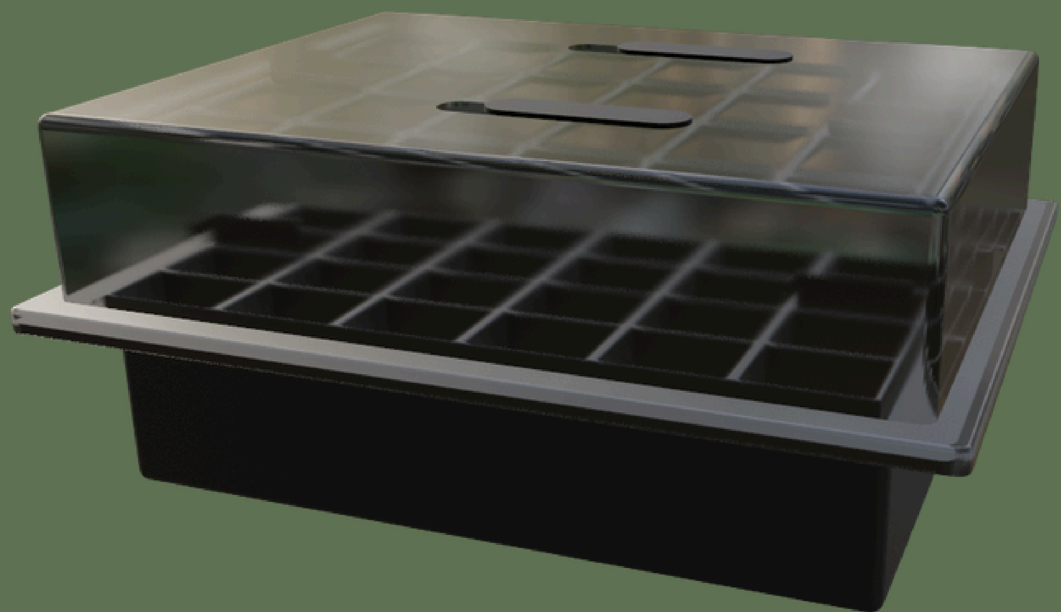




13.2.3 INLAY 3

The inlay consists of 24 compartments, each with a hole at the bottom, and fits perfectly into the bottom. The compartments are big enough for the plants to grow out of the 'seedlings stage'. After that, the plants can be put in a total of 6 P9 pots, allowing them to grow even bigger (***W5***, *Adjustability)*. Because there are many compartments, a wide variety of crops can be grown (***R4***, *Plant variety)*. If fewer types of crops are needed, multiple seeds of the same crop can be sown, allowing the strongest seedlings to survive. It is also helpful to sow slightly more seeds than needed, as not every seed will germinate.
The holes at the bottom serve a dual purpose. First, they allow any excess water to drain away. Second, when a seedling needs to be transplanted, it can be pushed up from the bottom using a small pin. This allows the grown seedling to be moved easily with minimal damage to the roots.
Finally, the inlay has two protruding edges, which the user can hold to lift the inlay out of the bottom when needed (***W2***, *Usability)*.

13.2.4 MOISTURE SENSOR

On the bottom of the tray the moisture sensor can be put on with magnets. The sensor can be placed in the soil to check whether there is enough moisture. The readings are indicated as follows:

- **Green**: Sufficient moisture in the soil (VWC between 25–40%).
- **Yellow**: Moisture is still adequate, but approaching dryness (VWC between 20–25%).
- **Orange**: The soil is too dry, but still slightly moist (VWC between 10–20%).
- **Red**: The soil is very dry (VWC between 0–10%).

These LED indicators clearly show the user when additional water is needed (***R2,*** *Water monitoring)*, making vegetable cultivation easier and more reliable. The code (sketch) and the breadboard scheme are shown in appendix 11.

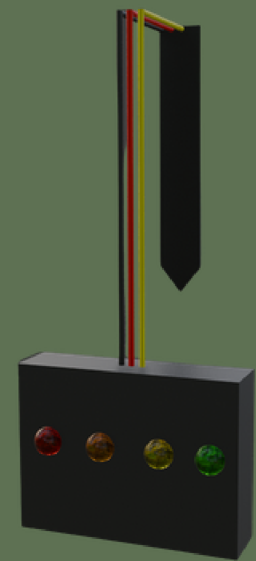


Figure 35: Moisture sensor

13.2.5 DIMENSIONS

The dimensions of the growing box are 35 cm (length) × 27 cm (width) × 15 cm (height). These dimensions were chosen primarily because the tray fits perfectly on a windowsill. The average depth of a windowsill generally falls between 20 and 30 cm, as explained in Chapter 3.3.5.

In addition, the base was designed to accommodate the dimensions of a P9 pot (9 cm × 9 cm × 10 cm). Once the seedlings have grown in the inlay, they can be transplanted into P9 pots, six of which fit perfectly in the base (2×3). This allows the design to be used beyond the sowing phase, extending its functionality (***W5***, *Adjustability)*.

13.3 PRODUCTION/MATERIAL CHOICES

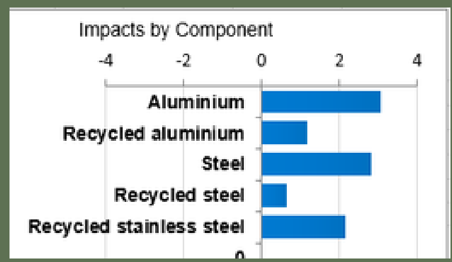
In this subchapter, the choices for recycled aluminium, pinewood, polypropyleen and the production of the growing trays will be explained.

13.3.1 RECYCLED ALUMINIUM

For the frame of the design, recycled aluminium was chosen. aluminium combines lightweight properties with high strength, making it ideal for a frame that needs to be both sturdy and easy to handle. To check this, a force (100N) test simulation has been done with solidworks. Only one aluminium pipe could already withstand 10 kg (see appendix 13).

Compared to recycled steel, aluminium offers similar structural strength while remaining much lighter, which improves usability and reduces transportation effort. Plastic poles were also considered; however, they are less strong compared to aluminium. Since sturdiness is an important requirement in the design, aluminium was therefore chosen.
In terms of environmental impact, recycled steel and recycled aluminium have a comparable eco-intensity during production, but aluminium has a significantly lower impact when recycled (figure 36). Recycling aluminium requires much less energy and produces less CO_2 than steel, making it an excellent choice for this design in terms of both functionality and sustainability. The filled in LCA sheet can be found in appendix 12.

MANUFACTURING



END OF LIFE

Figure 36: Impact by component. Manufacturing and end of life.

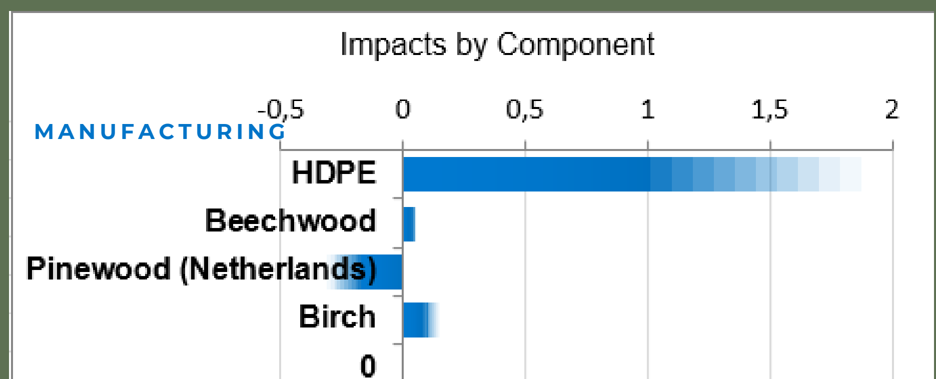
13.3.2 PINEWOOD

Initially, a comparison was made between wood and plastic. HDPE was considered as an option because it is very strong and suitable for bearing relatively heavy loads. However, this comparison showed that plastic has a significantly higher eco-intensity than wood, making it a less sustainable choice for the frame material.

Based on these findings, pinewood was chosen due to a combination of low cost, good workability, and low environmental impact. Firstly, pinewood is considerably cheaper than beechwood and birch, making it an attractive option for an affordable design. Although pinewood may initially appear less 'refined' than the more expensive wood types, it can be finished through sanding, staining, or oiling to achieve a visually comparable result while maintaining the lower cost.

Furthermore, as shown in figure 37, pinewood has a much lower eco-intensity than beechwood, birch, and HDPE (during the manufacturing stage). This makes pinewood an optimal balance between aesthetics, functionality, cost, and sustainability, making it the best choice for the frame of the design.

Figure 37: Impact by component, manufacturing



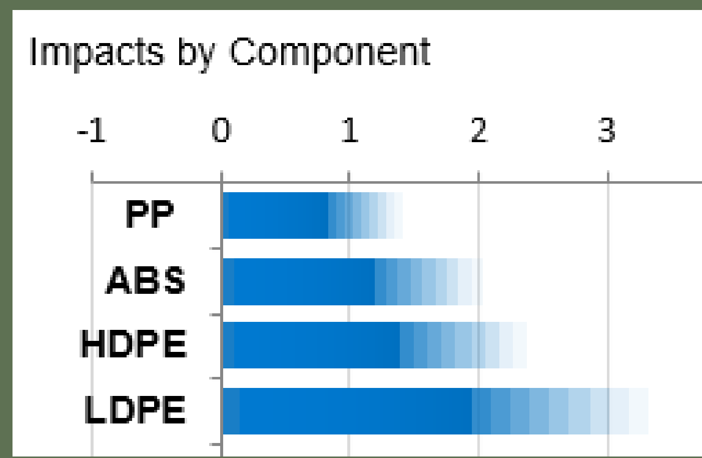
13.3.3 POLYPROPYLEEN

ABS, PP, and HDPE are strong materials with many similar properties, making them all suitable for sturdy growing trays. PP was ultimately chosen because it offers the same mechanical performance as ABS and HDPE, but with a significantly lower environmental impact (see Figure 38). The material requires less energy to produce, is highly recyclable, and is also cheaper than both ABS and HDPE. PP combines stiffness and impact resistance, ensuring the container reliably withstands daily stresses, and it is well-suited for both injection moulding and thermoforming, providing great flexibility in design and manufacturing. ABS is also strong and rigid, but more expensive and harder to recycle, while HDPE would require thicker walls to achieve the same performance as PP.

LDPE was included in the comparison because it is lightweight and flexible, but it is less suitable for this container: it wears out faster and cannot provide the required rigidity, resulting in a higher environmental impact over the long term.

Based on this assessment, PP offers the best combination of strength, durability, low environmental impact, cost-effectiveness, and processability, making it the most suitable choice for this application.

MANUFACTURING



END OF LIFE

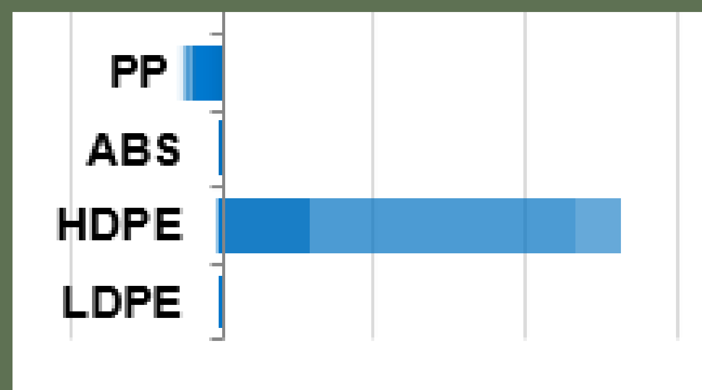


Figure 38: Impact by component. Manufacturing and end of life.

13.3.4 PRODUCTION GROWING TRAYS

For the production of the growing tray, a combination of injection moulding and thermoforming is selected. The inlay and the lid contains complex details such as thin walls and small holes, which require high precision and consistent quality. Injection moulding is therefore used, as it allows accurate reproduction of complex geometries and high repeatability (Hertz et al., 2022) (see figure 39).

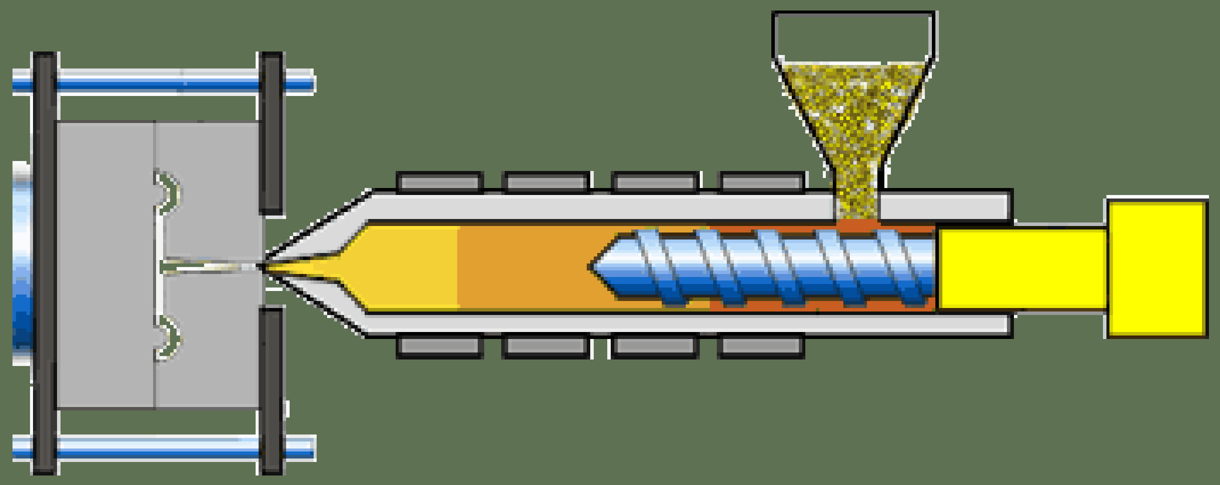


Figure 39: Injection moulding (Toolcraft plastics, n.d.)

The bottom has a relatively simple, flat geometry with limited detail. For this part, thermoforming is a cost-effective and efficient manufacturing method with lower tooling costs and fast production setup.

By combining these two production techniques, an optimal balance is achieved between product quality, production cost, and scalability.

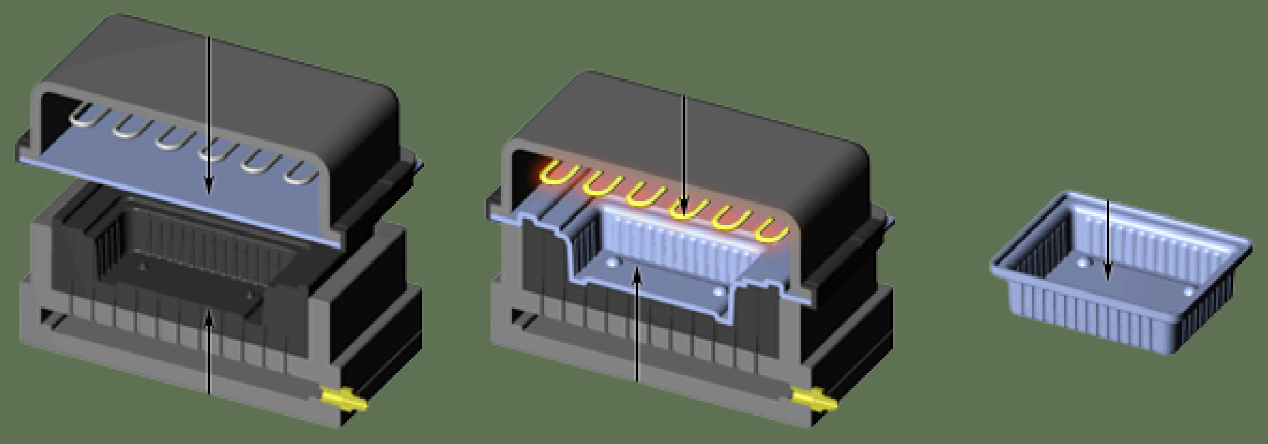


Figure 40: Thermoforming (CustomPartNet, 2023)

13.3.5 PRODUCTION COSTS

The production costs are shown in Table 9. Please note that this is an estimate of the total costs. These figures have been calculated conservatively and may ultimately differ from the actual total production costs. The whole calculation and sources can be found in appendix 14.

What	Costs (€) per product
Materials: 1. Aluminium 2. Pinewood 3. PP	1. €0,60 2. €4,80 3. € 1,00
Processing costs: 1. Aluminium holes/cuting 2. Aluminium powdercoating 3. Pinewood sawing 4. Pinewood sanding 5. Pinewood pickling 6. Pinewood milling 7. PP malls, production	1. € 1,95 2. €5,57 3. €2,00 4. €4,95 5. €1,98 6. €1,98 7. €2,00
Electronics: 1. Moisture sensor 2. Leds 3. Led strips	1. €1,00 2. €0,10 3. €4,50
Other: 1. magnets 2. Leg button clips	€0,075 €3,44
Total	€35,-

Table 9: Production costs

13.4 APP

To convey the desired information to the user, it was decided to do this through an app. An app is user-friendly, clearly readable, and always within reach. This subchapter provides an overview of the app's various features, including explanations. The app highlights the most common challenges for beginner gardeners (also shown in Chapter 7.3). For example, novice gardeners often have questions such as: "When should I sow?", "How much should I sow?", or "How deep should my seedlings be?". The app guides the user step by step on how and when to sow, addressing these major challenges for beginners. In addition, the app includes features such as notifications and a community where users can share and receive extra information. A selection of these features will be shown, while the rest can be found in Appendix 15. The numbers of the 'homepage' on the left of the page correpsond with the numbers with explanations.

The app is designed in such a way that everyone can use it. Icons and images support the text, making the app intuitive to use. This corresponds with (*R7, Simplicity & Intuitiveness*).

The "Sowing and Harvest Calendar" provides an overview of when to sow (green bars) and when to harvest (yellow bars). By clicking on a specific crop, you can access additional information about the conditions it grows in and the timeline of its growth (including explanations of the definitions). This gives a clear overview of when to sow and harvest each crop and what the different growth stages look like. There has been made a selection of 13 different crops, all suitable for beginner gardeners, as these are relatively easy to grow. This correspomds with (***R4**, Plant Variety*).

"This Month in the Garden" shows what tasks can be done during the current month. For each month, there is an overview of everything that can typically be done in the garden. Some months are busier than others, but there is always something to do.

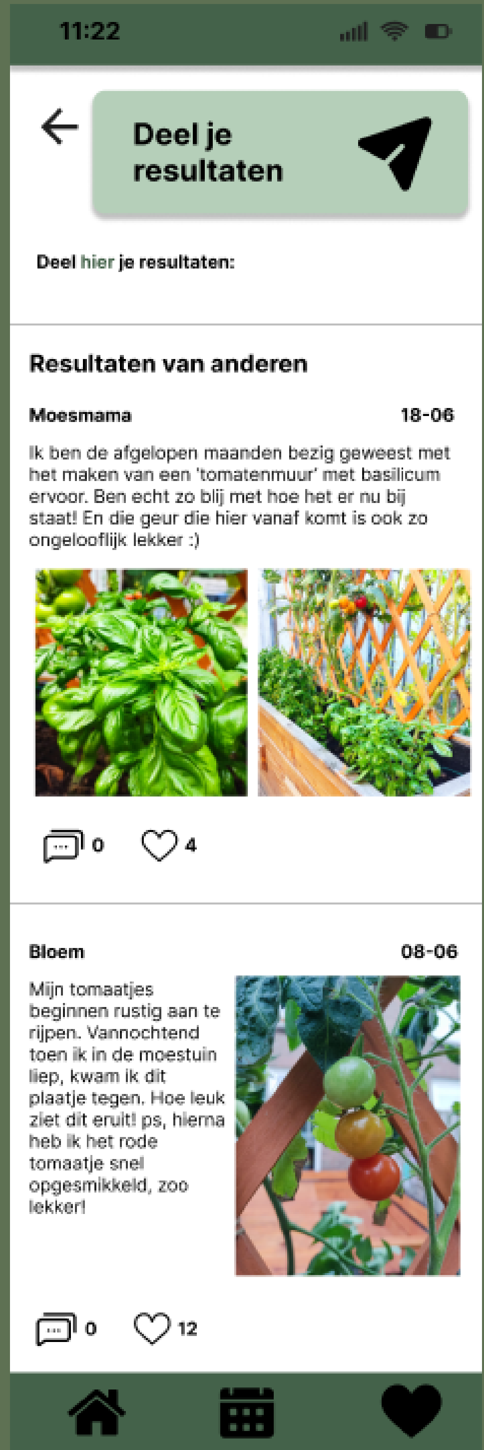
In the "Sowing" tab, you are guided step by step on how to sow a specific crop. First, you receive information about the crop itself, followed by detailed instructions on how to plant the seedlings. This includes what you need, how deep and how many seedlings to plant, how much water they require, and the best conditions for optimal growth, such as light and temperature.
People learn actively which corresponds with (***R1**, Seed planting and **R12**, Active Learning*)

4

5

6

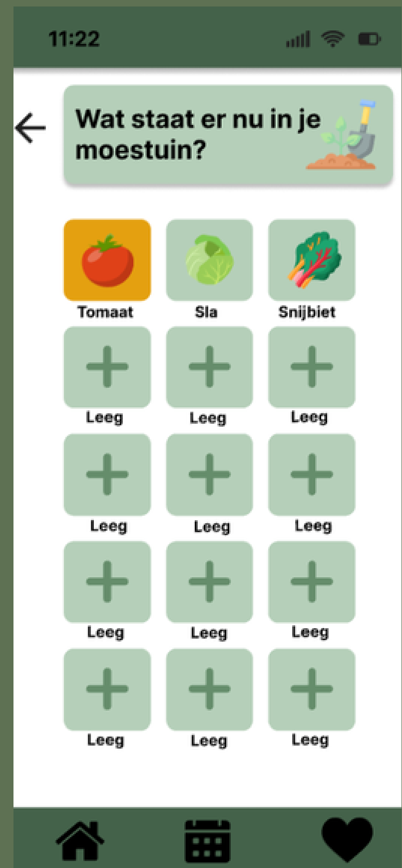
7



In the community, you can connect with others. You can share what you have grown yourself, but you can also see what others are doing to learn more. Additionally, there is the option to ask questions if you get stuck. This way, you can enjoy the growing process together with others.

5

The app also provides notifications about the growth stage of your plant. This way, you can see whether it is growing properly and receive additional information if something is not going as expected. In this way, the user can **learn by doing (R12,** *Active Learning and* ***W3****, Visible Progress).*



6

The calendar shows what is currently in your garden and what you can do with your crops at that time. This provides a clearer overview of what you have planted and what tasks you can focus on during that period.

7

The heart tab provides an overview of all your favorites so they can be quickly found. The user can add or remove when wanted.

13.5 REFLECTION DESIGN 1

During the green light presentation, feedback indicated that the next phase of the project should focus more strongly on detailing and technical development of the design. While the overall concept and functionality are clear, further refinement is needed to make the design suitable for production and implementation. In particular, the frame and growing trays require additional attention regarding, dimensions, manufacturing methods, assembly techniques, and structural performance. Elements such as tube thickness, stiffness, and robustness need to be evaluated to prevent potential weaknesses, for example in the corner connections where diagonal loads could lead to instability or failure.

In addition, the integration of electronic components requires further development. The positioning and integration of LED strips, moisture sensors, indicator LEDs, wiring, and the power supply need to be clearly defined, ensuring both safety and logical integration within the product. The moisture sensor itself should not be treated as a separate element, but as an integrated part of the overall system and user interaction.

The feedback also emphasized the importance of developing the design to a level where it could realistically be transferred to a manufacturing context. This means reconsidering design decisions beyond the first practical solution and evaluating alternatives, such as frame segmentation, tray placement and fixation, and the integration of components within the structure.

As a next step, the design will be further detailed by optimizing material thickness and robustness, refining construction and assembly solutions, and reviewing all components for potential improvements. This development phase will be supported by detailed renders or prototypes showing the product in different stages of use, as well as an exploded view to clearly communicate the product structure and components.

FINAL DESIGN

In this chapter, the final design will be explained. Just like in iteration 1, it is divided into subchapters for the frame, the growing box, and the app. Some components will have been changed, while others remain the same and/or have been supplemented. Whenever components remain the same or have been supplemented, this will be clearly indicated and, if necessary, referenced back to iteration 1.

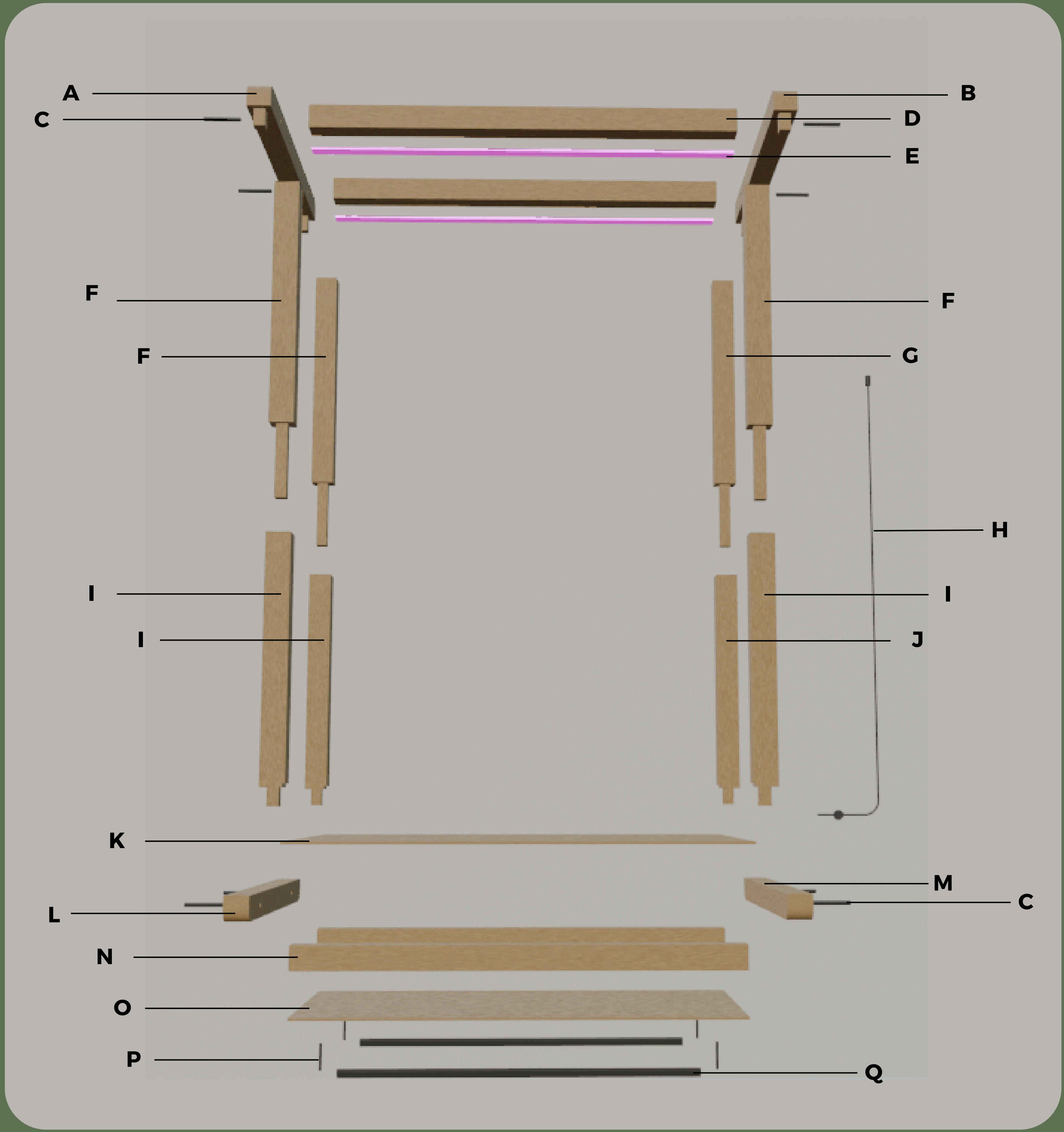


Figure 41: Exploded view final design frame

14.1 FRAME

The frame in the final design consists of several components: the wooden frame, the LED lights with a timer, and the wiring. These components will be further elaborated in this subchapter.

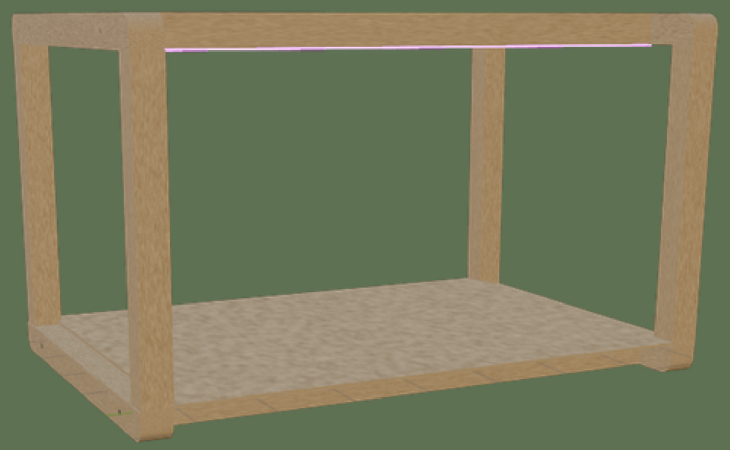


Figure 42: Whole frame

14.1.1 WOODEN FRAME

The fully wooden frame from pinewood (as the same reason told in chapter 13.3.2) consists of several components that can be slotted together or screwed in place. A step-by-step explanation of how the frame is assembled will be provided. An exploded view can be found in Figure 41 on the previous page, and an overview of the different components is provided in Appendix 16.

1. **Top frame:** The top frame will be assembled with screws just once. It consists of two long beams, which house the LED lights, and two short beams, into which the posts can be inserted. The short beams feature an extrusion, and the top part of the posts has a corresponding cut, allowing them to slide together easily. Additionally, the top frame includes a slot where another frame can ultimately be placed to ensure stability *(**R9**, Sturdiness)* (Figure 43).

Figure 43: Top frame

2. **The posts**: The aluminium telescopic posts used in iteration 1 have been replaced with two fixed-length wooden posts. The reason for this change is that the aluminium tubes in the corners of the frame could make the structure vulnerable. The tubes might bend or break out of the frame under diagonal loads *(**R9**, Sturdiness)*. A brainstorming session for this component was conducted again, which can be found in Appendix 17.

It was ultimately decided to replace the aluminium telescopic posts with pinewood posts (as the same reason told in chapter 13.3.2). There are now two fixed lengths of 20 cm, which can easily be slotted into the top and bottom frames using a sleeve-and-post mechanism *(**R8**, Practical use)*. Both posts have cuts and extrusions that fit together precisely, which will be milled. At the connection between the two posts themselves, an extrusion/cut of 6 cm depth was chosen to ensure that the posts fit securely together and do not easily come apart or slide, while also preventing them from breaking easily (see Figure 44).

During the germination phase, the first height of 20 cm is sufficient. The plants initially germinate with the lid on the growing box and continue growing without the lid afterwards. When the plants grow larger and can be transferred to a P9 pot, the second level can be added *(**W5**, Adjustability)*. In this way, the seedlings in the germination phase and the vegetative growth phase have enough space to grow properly *(**R4**, Plant variety)*.

Figure 44: Sliding wooden poles

3. **Bottom frame:** Like the top frame, the bottom frame consists of two long beams and two short beams that are assembled with screws just once. In addition, the bottom frame includes two wooden panels, 2 mm thick, made of birch plywood. This material was chosen because it is both moisture-resistant and strong for its thickness (better than pinewood and Beechwood shown in the LCA in Figure 37 in the previous chapter). The lower panel is attached beneath the bottom frame with screws. It serves as a base where the individual posts can be placed when not in use or for storage of the entire frame *(**R11**, storage)*.

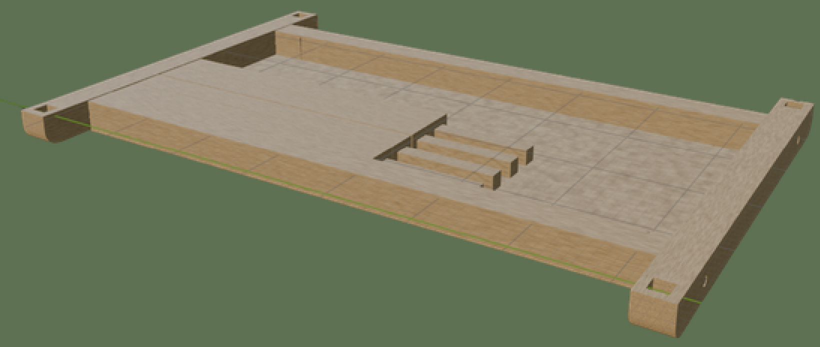


Figure 45: Base frame

Rubber triangles can be inserted into the bottom of the lower panel. These ensure that the frame remains stable and does not slide *(**R9**, Sturdiness)*, but they can also be placed on top of another frame. The triangles allow the frames to remain securely stacked in this way (Figure 47). This setup also enables more efficient use of space *(**R6,** Space efficiency)*.

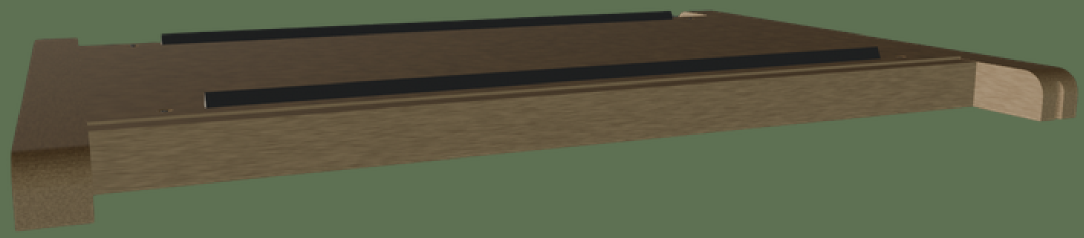


Figure 46: Base frame with rubber triangles

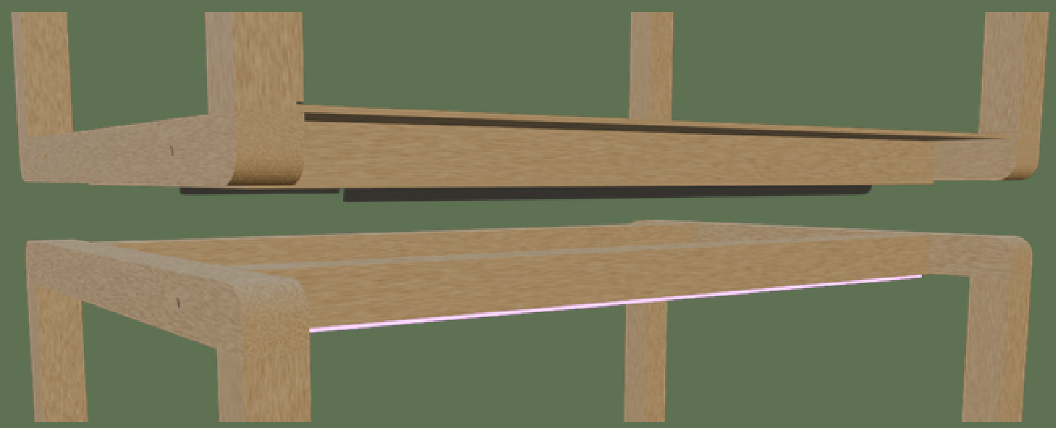


Figure 47: Frames on top of each other

Finally, the bottom frame also includes a second panel made from birch, which will be slid on top of the base panel. This panel serves as the foundation on which the growing box will be placed. In iteration 1, this was a corner line, but after a brainstorm (appendix 19) , this seemed a better option. The lower posts of the frame have a notch where this panel can be inserted. This allows the panel to be easily slid in and out of the frame while still remaining securely in place *(**R7**, Simplicity & Intuitiveness).*

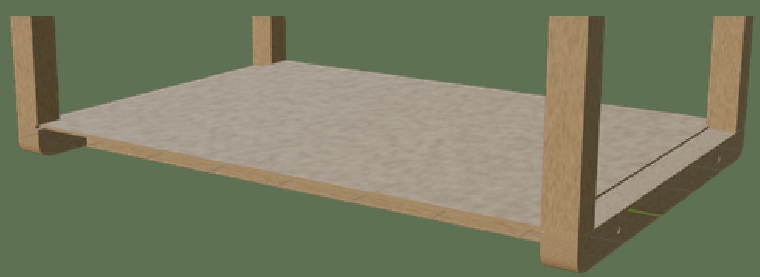


Figure 48: Base frame with upper plate

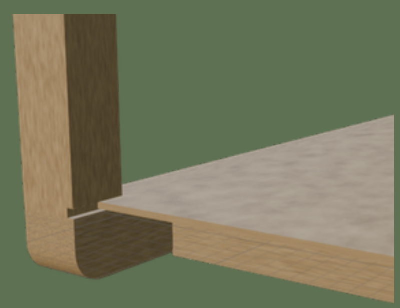


Figure 49: Slide-in mechanism

Once the (pre-)sowing phase is over, the frame can be easily stored. The posts can be laid in the bottom frame (Figure 50). On top of them, the top frame can be placed (these fit together precisely) (Figure 51). In this way, a flat frame remains (along with any loose cables), which can be slid into a bag and closed. This allows the frame to be stored safely while keeping all components together *(**R11**, Storage and **R10**, Reusable)*. The bag is made of organic cotton, a durable and strong material that is easy to clean. In addition, it gives a natural look that fits the product perfectly.

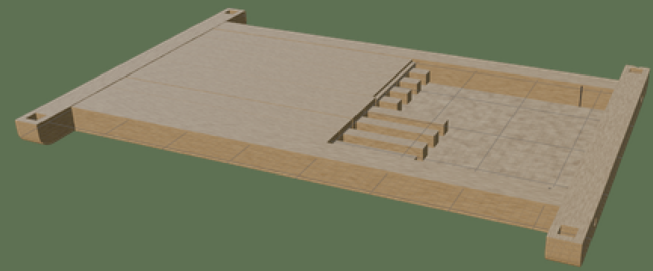


Figure 50: Base frame with all poles inside.

Figure 51: Frame taken apart and put on each other.

Figure 52: Cotton bag for storage

14.1.2 DIMENSIONS

The dimensions of the frame are as follows: length 37 cm, width 28.5 cm, height 20 cm or 40 cm. The square posts measure 2 × 2 cm. The reasoning behind these dimensions is as follows:

- Firstly, the length was designed to fit the growing box precisely. There is minimal clearance around the growing box to use as little material as possible, but still easy to get it in.
- The width was determined both by the dimensions of the growing box and the depth of a windowsill. The user can choose where to place the frame. Research showed (Chapter 4.3.5, Windowsills) that the average windowsill depth is between 20 and 30 cm. The points of the frame that rest on the windowsill fall within this range.
- The height of the frame is based on how tall the plants can grow. For the first height (20 cm), the LED light is positioned just above the growing box, which is 14.6 cm high. When the plants grow larger and can be transferred to a P9 pot, they reach approximately 25 cm (so 35 cm including the P9 pot within the frame). Therefore, a second level was designed with the same height of 20 cm.
- The thickness of the posts was chosen for two reasons: it must be sturdy (R9, Sturdiness) and still aesthetically pleasing (W6, Aesthetics). A force test was performed in SolidWorks to determine the load a double 2 × 2 cm post could bear, which was 40-50 kg (see Appendix 18). To keep the frame from becoming too bulky while maintaining strength, a thickness of 2 × 2 cm was selected.
- Finally, the cuts and extrusions needed to be strong enough to slide together securely.

14.1.3 LED LIGHTS

The frame includes LED lights. When sowing indoors, it is often observed that heat and light are not balanced. The temperature indoors is frequently too high, relative to the amount of light, especially when starting sowing in February, which can result in leggy seedlings. To prevent this, LED lights have been added to the design. This allows the product to be placed anywhere in the home, making it independent of the light coming through a window *(**R8**, Practical use and **W2**, Usability/several locations).*

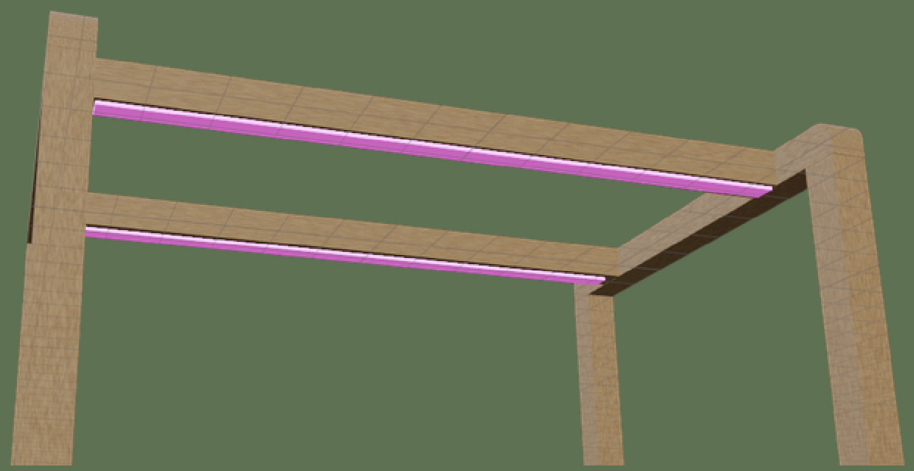


Figure 53: Led light in frame

The color of the LED light is pink, which is a combination of red and blue light. The blue light promotes healthy leaf growth, while the red light supports root development and germination (see Chapter 6.3, Light). In this way, the seedlings can grow optimally.

Seedlings typically require 12–16 hours of light per day. When the plants reach the vegetative growth stage, they generally need 12–14 hours of light per day. To accommodate both of these needs, a timer switch has been added, ensuring that the LED light will stay on for 14 hours. When the user presses this timer switch, the 14-hour cycle begins. This duration provides sufficient light for healthy seedling development while avoiding unnecessary energy consumption. A fixed cycle was deliberately chosen instead of user-adjustable settings to keep the system intuitive and accessible for beginner users *(**R7,** Simplicity & Intuitiveness).* This reduces the risk of incorrect use and supports a low-threshold learning experience.

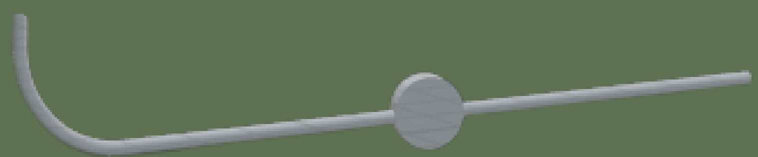


Figure 54: Timer switch

14.1.4 CABLING

The wiring for the LED light runs through the right short beam (Beam B in Figure 41). It exits at the back so that it remains as unobtrusive as possible for the user. At the rear right posts, there is a notch where the wiring can be inserted, ensuring it stays securely in place (Figures 55 and 56).

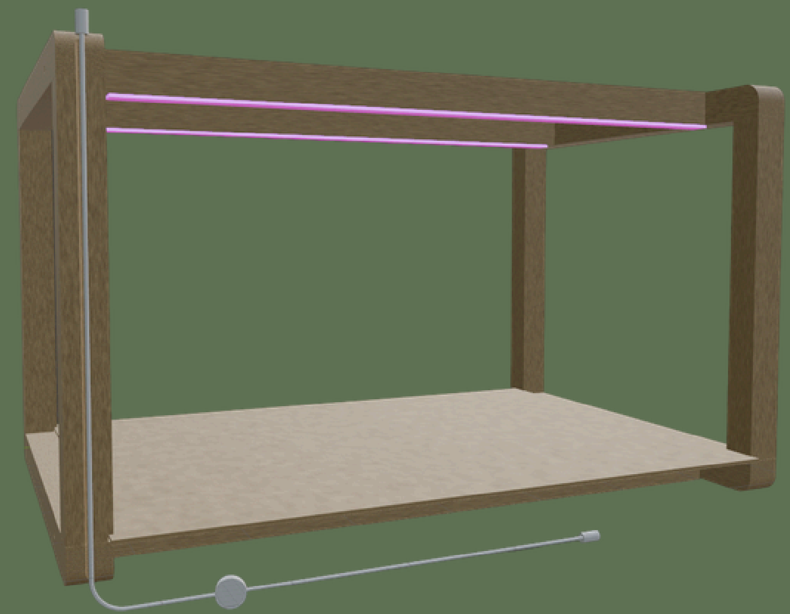


Figure 55: Cabling at the back side of the frame

Figure 56: cut in wood for cabling

To improve safety and make the product more suitable for indoor use, the LED lighting is powered through a low-voltage system. An off-the-shelf 12V adapter converts the mains voltage externally, so only low voltage enters the product. The adapter connects to the frame through a single power cable, after which the LED strips and other electronic components are powered internally.

A 12V system was chosen because it allows the LED strips to be powered efficiently across the length of the frame while reducing current, heat generation, and voltage drop. This makes the system safer and more reliable, especially in a product where electricity and water are used in close proximity, and helps create a more practical solution for real-world use.

Additionally, DC connectors are used so that when two frames are stacked on top of each other, they can share the same power source and timer. This eliminates the need for an extra cable to the wall outlet, allowing both frames to receive power from the same supply *(**R7**, Simplicity & Intuitiveness).*

Figure 57: DC connector

14.1.5 PROTOTYPE FRAME

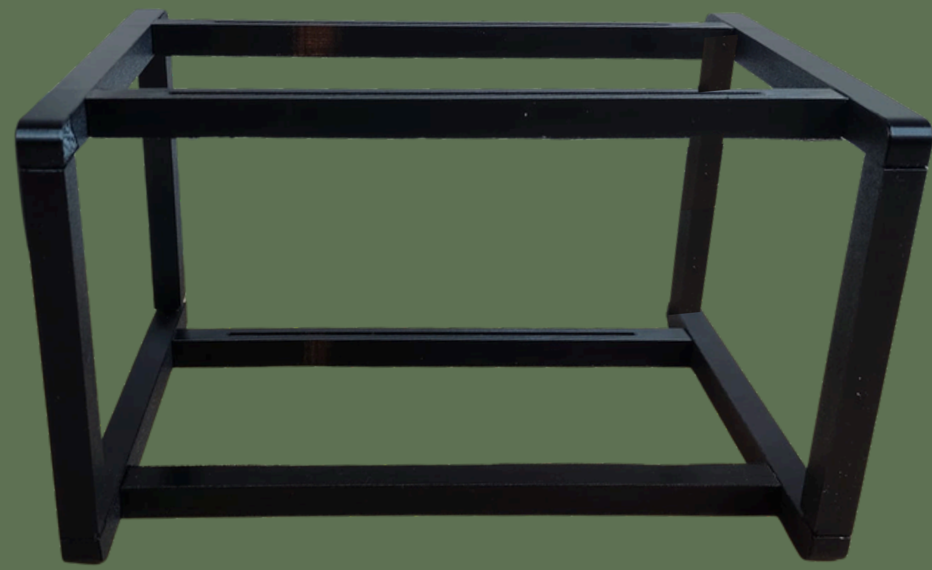
To test the functionality of the frame, a 3D-printed model was created. This was done to determine what works well and what does not. Although the model was made from PLA instead of pinewood, it provides a clear understanding of how the frame functions.

It was particularly important to test whether the two fixed-length wooden posts could slide smoothly into each other using the sleeve-and-post mechanism. Would this work as conveniently as expected, or would it prove less practical? The results showed that the posts slid together easily and that adjusting the height was simple, as intended.

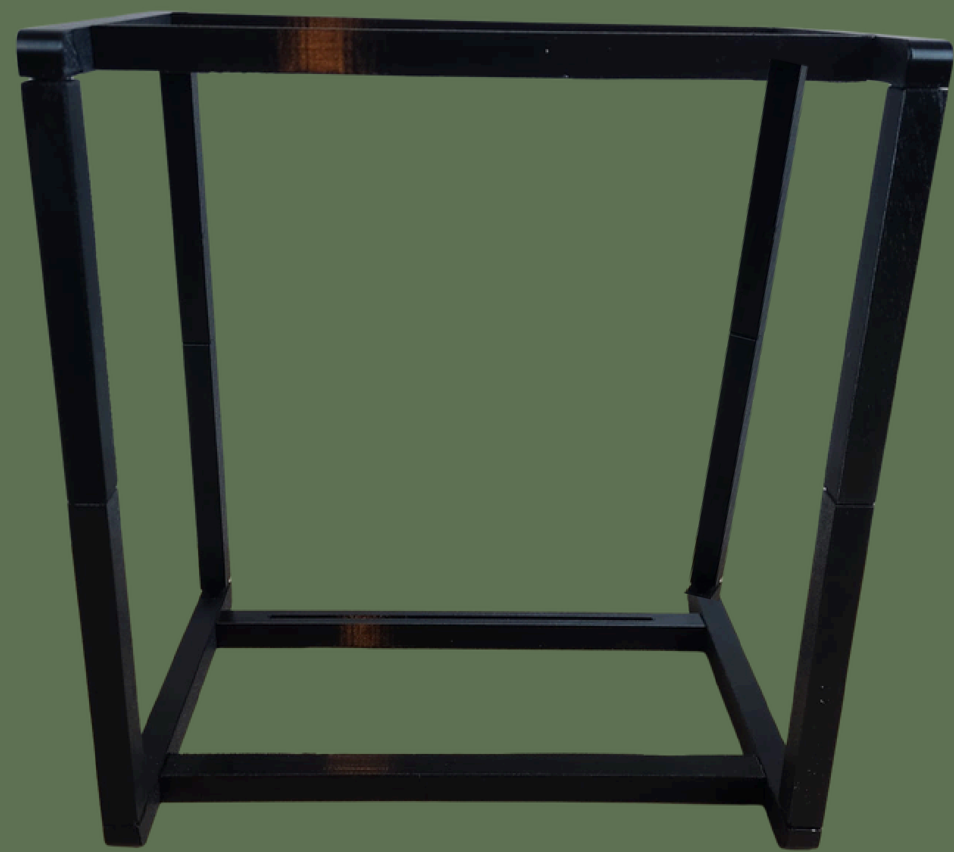
The model also demonstrated that the frame is very sturdy and that the growing tray developed earlier (see Chapter 13.7) fits properly within the structure.

HEIGHT 1 WITH GROWING TRAY (BOTTOM AND INLAY)

SLEEVE-AND-POST MECHANISM



HEIGHT 1



HEIGHT 2

Figure 58: 3D printed frame

14.2 GROWING TRAY

This subchapter will focus on the growing tray. No major changes have been made to this component of the design from iteration 1. This chapter will cover the points that have been modified, while the smaller parts of the base and lid, the inlay, dimensions, material, and overall product remain the same as in iteration 1 (see Chapter 13.2).

14.2.1 BOTTOM

In iteration 1, the lid fits over the base. This fits perfectly; however, a disadvantage was that if there was moisture in the tray and the ventilation slides were closed, water could escape along the edges. In the final design, the base has been given a raised edge, which captures any water that may seep down along the lid, keeping it contained within the bottom itself (Figure 59). The rest of the bottom remains the same as in iteration 1.

14.2.2 LID

The lid has first been adjusted to fit the new base. It no longer fits over the base but instead fits inside it. Additionally, a suitable location needed to be found for the housing of the moisture sensor (which contains the LEDs and the PCB). It was decided to place it on the lid so that it sits as close as possible to the soil being measured. Placing it inside the lid would bring it even closer, but this is not ideal due to moisture concerns. In iteration 1, the sensor was placed on the base. Initially, this seemed very convenient, but over time, as the plants grew and the lid could move off the base, the sensor housing no longer fit properly. Therefore, it was decided to attach it to the lid using magnets. This allows it to be easily placed, removed, and rotated when needed in every growing stage.

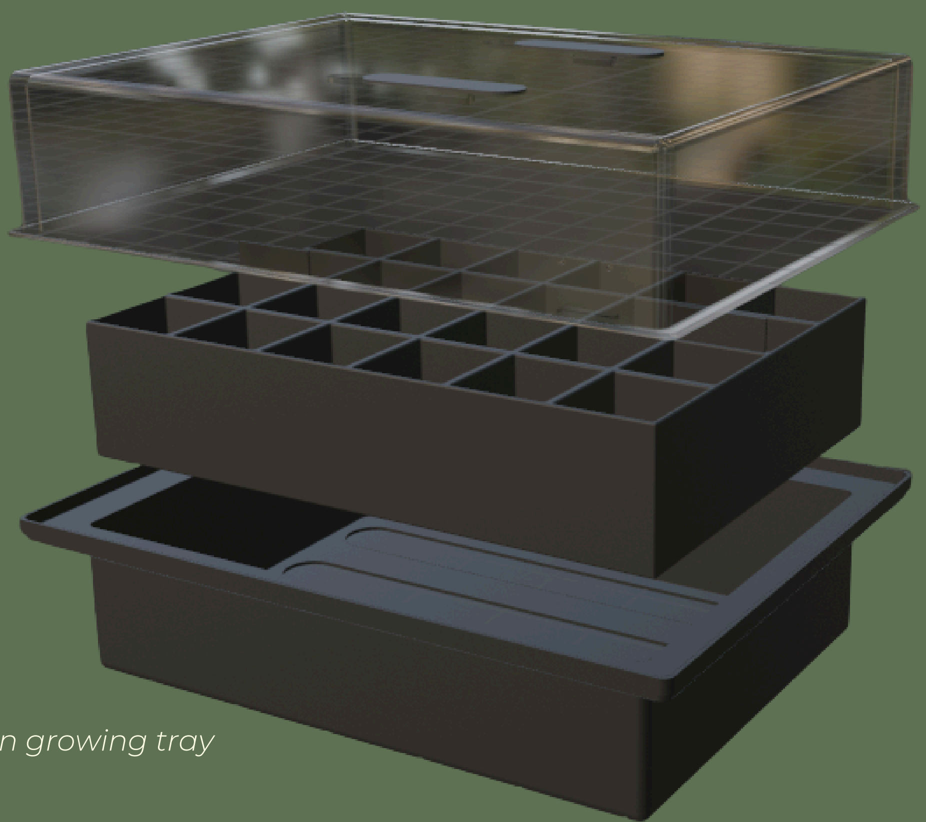


Figure 59: Final design growing tray

Since the housing of the moisture sensor (including the LEDs) is attached to the lid, the sensor itself must somehow reach into the tray. To achieve this conveniently, a small slot measuring 2 × 25 mm was created in the lid, through which the moisture sensor (1 mm thick and 23 mm wide) can pass. In this way, the housing, which is not resistant to significant moisture, remains on the outside, while the sensor can still reach the inside of the tray (see Figure 60).

Figure 60: Slot moisture sensor

14.2.3 MOISTURE SENSOR

The cap of the moisture sensor itself has also been significantly changed. In iteration 1, it could indicate four levels: too dry (red), almost too dry (orange), nearly optimal (yellow), and good (green). This has now been updated to the following values:

- Red: The soil is very dry (VWC between 0–10%)
- Yellow: Not too dry, but not moist either (VWC between 10–25%)
- Green: Sufficient moisture in the soil (VWC between 25–40%)
- Blue: Too much moisture (VWC above 40%)

In iteration 1, the difference between the orange and yellow levels was very small, making this distinction inefficient. Therefore, these were combined into a single yellow level. Additionally, beginners often overwater plants, which was not accounted for in iteration 1. To address this, a blue LED was added to indicate excessive moisture in the soil *(**R2**, Water monitoring).*

Additionally, the LED housing itself indicates what each LED color represents. In this way, it is clear what actions need to be taken without additional instructions *(**R7**, Simplicity and Intuitiveness)* (see Figure 61).

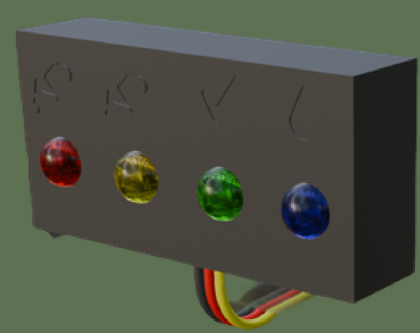


Figure 61: Box moisture sensor

14.3 APP

Since most of the iteration is focused on the physical product, few changes were made to the app. However, a few features have been added, which will be explained in this chapter. The rest of the app can be found in iteration 1, Chapter 13.4: App. Again, the numbers on the "homepage" on the left of the page correspond with the numbers in the explanations of the features.

Because it is important that a first-time user can get started easily using only the provided instructions, an explanation of how to assemble the product is included in the app (***R7***, *Simplicity & Intuitiveness*). The app provides a step-by-step guide on assembling the product, along with additional information. This feature can be seen in Figure 62.

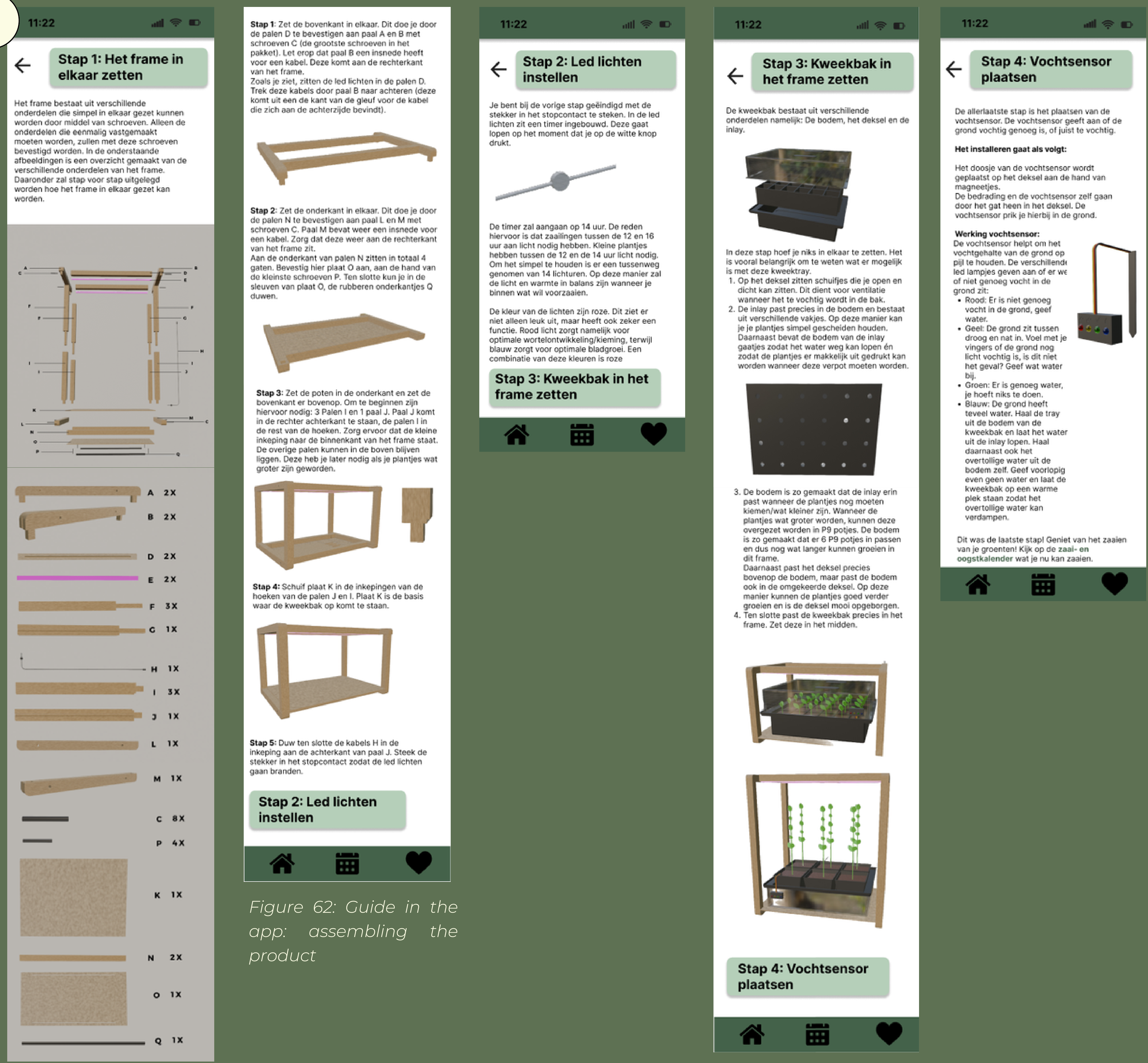


Figure 62: Guide in the app: assembling the product

14.4 AESTHETICS

In this subchapter, the aesthetics of the final concept will be further explained. The use of wood, shapes, colors and the production costs will be substantiated **(W6**, aesthetics).

14.4.1 WOOD

The frame is made of pinewood to create a natural and warm appearance that supports the product's goal of encouraging a stronger connection with plants and nature.

Additional research indicates that wood is associated with comfort and calm, and many people also associate it with sustainability and environmental responsibility. This makes wood a suitable material choice for a product that promotes growth, care, and long-term use. In contrast, plastic is often perceived as functional but less warm and less emotionally engaging (Kwak & Choi, 2025).

Choosing wood therefore helps the product feel more inviting, environmentally conscious, and appropriate for use in a home environment.

14.4.2 SHAPES

Additional research shows that rounded shapes are generally perceived as friendlier, more comfortable, and more positive than angular shapes, which are associated with strength, structure, and precision. Rounded forms evoke feelings of safety and calm, which aligns well with products related to plants and well-being.

Angular shapes are used in the corners and straight sections to emphasize stability, clarity, and a modern, technical character. Rounded edges are applied in user-interaction areas to improve comfort and approachability (Palumbo et al., 2015), (Manippa et al., 2023)

In te final design, this will be combined which creates a balanced design that feels both functional and inviting, making it suitable for a home environment.

14.4.3 COLOR GROWING TRAY: BLACK

Market research shows that consumers in residential environments generally prefer neutral and natural color schemes for furniture and household objects. White and black are often perceived as calming and timeless, while black is also associated with elegance, modernity, and clarity (Van der Voordt et al., 2017).

For the final design, a combination of black accents and wood was therefore chosen. The black elements give the product a modern and refined appearance and emphasize its clean lines and technical character. The wooden components, on the other hand, add warmth, playfulness, and a natural quality, reinforcing the connection to sustainability and living materials.

Together, this combination creates a balanced contrast between a contemporary, high-end look and a welcoming, organic feel. As a result, the design appears both chic and warm, making it suitable for integration into a home environment without dominating the interior.

14.4.4 CONNECTING WITH NATURE

One of the wishes (**W4**, connection to nature), and an important objective of this project, is to strengthen the user's connection with nature. This subchapter explains how this connection is supported through different design decisions.

As described in Chapter 3.2, people connect with nature in different ways. The design therefore enables this connection on multiple levels, combining material, interaction, and learning:

1. First, the choice of material plays an important role. Wood was selected for its natural character and sustainable appearance, allowing the product to feel more connected to natural environments rather than purely technical indoor products. The visual and tactile qualities of the material can already evoke a sense of closeness to nature.
2. In addition, soil was deliberately chosen as the growing medium instead of alternatives such as hydroponics. Handling soil when filling the inlay or P9 pots creates a direct, sensory interaction with nature. The physical act of working with soil, getting one's hands dirty, and experiencing its smell contributes to a more tangible and personal growing experience.
3. Finally, the app supports this connection by increasing the user's understanding of natural processes. Through learning about sowing, growth stages, and plant care, users become more aware of how plants develop and how their actions influence this process. Although the interaction takes place digitally, it strengthens the user's engagement with nature through knowledge and awareness.

14.5 PRODUCTION COSTS

The production costs are shown in Table 10. Please note that this is an estimate of the total costs. These figures have been calculated conservatively and may ultimately differ from the actual total production costs. The whole calculation and sources can be found in appendix 20.

What	Costs (€) per product
Materials Frame: 1. Pinewood 2. Birch	1. €9,60 2. €6,20
Processing costs: 1. Pinewood/Birch sanding 2. Pinewood/Birch pickling 3. Pinewood milling 4. PP malls, production	1. €5,29 2. €2,12 3. €2,12 4. €4
Electronics: 1. Moisture sensor 2. Leds 3. Led strips 4. Led strip connectors 5. Dc-connectors 6. PCB 7. Digital timer module	1. €1,00 2. €0,08 3. €5.67 4. €0,95 5. €0,53 6. €0,40 7. €4
Other: 1. magnets 2. Storing organic cotton bag 3. Packaging cardboard	1. €0,075 2. €3,55 3. €0,90
Total	**€47,46**

Table 10: Production costs final design

VALIDATION

15

15.1 FEASIBILITY

The Smart Growing System is feasible due to the combination of existing technologies and straightforward mechanical design. The frame uses lightweight pinewood and birch panels, which are readily available and easy to process, ensuring structural stability.

The growing tray is made of polypropylene, which is compatible with both injection molding and thermoforming, allowing precise and scalable production. Components such as LED strips and capacitive moisture sensors are standard, commercially available, and compatible with small-scale indoor gardening systems.

Some functions have already been tested such as the moisture sensor, the growing tray and the frame. These are made from PLA which will not be the final material. Still it is a really nice test to see if everything works well (together).
The integration of the app for sowing guidance is feasible as it relies on existing smartphone platforms.

Beyond demonstrating feasibility, this project develops a new approach for indoor smart gardening: a modular system that combines hands-on learning with guided automation, designed specifically for novice gardeners with limited space. By combining compact physical design with app-driven knowledge transfer, it opens a pathway for future home gardening systems that are both educational and practical, offering a new standard for indoor seed starting solutions.

15.2 DESIRABILITY

The Smart Indoor Growing System addresses the main challenges of novice gardeners identified in the research: knowledge gap and lack of space. By providing clear step-by-step guidance in the app, users gain confidence and knowledge, reducing frustration and increasing motivation. Real-time feedback from the moisture sensor ensures that the learning process is interactive, aligning with the desire for visible progress.
Although many growing trays already exist, this system stands out by combining a space-efficient, modular frame with integrated moisture sensors and a supportive app. This combination creates a product that is not only practical but also interactive and educational, adding unique value to the market.
Its modular and compact design fits easily into the small spaces of typical urban homes, making it possible for users to enjoy gardening even if they only have a small windowsill.

The combination of hands-on seed sowing and gentle automation supports learning by doing, fulfilling the need for active engagement rather than passive observation. Additionally, the system creates new value for users and the wider community by encouraging sustainable practices, awareness of plant growth cycles, and healthy, self-grown produce. It offers a meaningful, educational, and emotionally rewarding experience, turning a practical product into a tool that enriches users' lifestyle and deepens their connection with nature.

15.3 VIABILITY

The Smart Growing System is viable because it is designed with affordability, durability, and long-term user engagement in mind. With an estimated production cost of around €47 per unit (which will result in a retail price of (100-150 euros), the system is much more affordable than many existing smart growing systems. These often use complex electronics and full automation and therefore end up being far more expensive for consumers. This makes the product accessible to a wider group of users, while still remaining realistic for large-scale production.
The chosen materials (pinewood, birch, and PP) offer a good balance between cost, strength, and sustainability. They ensure a long product lifespan, require little maintenance, and can be recycled or reused at the end of their life, helping to reduce environmental impact.

The modular structure of the system increases its economic resilience and scalability. Individual components such as frames, growing trays, and sensors can be produced and sold separately, enabling users to expand or replace parts instead of purchasing an entirely new system.
The app further enhances viability by enabling updates, notifications, and community support, fostering continuous engagement and brand loyalty. Through the community building, users become fans and ambassadors which helps growing the app and thus the product alive. By addressing both physical and digital aspects of gardening, the system ensures long-term relevance in the indoor gardening market.

Although everything seems to work well at the moment, for viability it is important that the product will be tested through the whole season. This way, things that do and do not work come to light.

Furthermore, the project sets an example for how home gardening products can combine sustainability, learning, and a positive user experience. It shows that small indoor growing systems can offer more than just productivity; they can also support education, mental well-being, and awareness of nature and the environment. This positions the project as a fresh and innovative approach within the home gardening field, offering a meaningful, sustainable, and socially responsible way of developing products.

DISCUSSION & RECOMMENDATIONS

16

16.1 DISCUSSION

During the design process, several promising features were developed, but some aspects of the system remain untested and require further evaluation.

Firstly, sleeve-and-post mechanism for the frame has been designed to allow easy height modification and stacking of multiple levels. The prototype from PLA and the simulations show it works well. It is important to test its usability, strength and stability with pinewood. It remains uncertain whether the mechanism functions as smoothly as the prototype and whether users find it intuitive and practical.

Secondly, the supporting app has been designed and prototyped in the program Figma. While the interactive flow and interface are clearly defined, the app has not yet been developed in a functional platform. Therefore, features such as notifications, growth tracking, and community interactions cannot yet be fully assessed for usability or effectiveness.

Finally, the complete system, including the frame, growing tray, LED lighting, moisture sensor, and app integration, has not yet been tested as a whole. The combined functionality is crucial to ensure that seedlings grow optimally, that sensors provide clear guidance for beginners, and that the app effectively supports learning. As the physical product has not been fully built, these comprehensive tests remain outstanding.

In general, the discussion highlights that while the design vision and individual components are promising, the project is currently limited by the lack of full-scale integration testing.

16.2 RECOMMENDATIONS

Based on the discussion, a few key steps are recommended to further develop and validate the Smart Growing System:

1. Test the sleeve-and post mechanism with pinewood: Build the complete frame and test it in real conditions. This will help confirm that the system is stable, easy to adjust, and simple for beginners to use. Feedback from actual users will show whether it really works as intended and feels intuitive. Also test another scale mechanism, are there better options?

2. Develop a fully functional app: Move the Figma prototype into a working mobile app. This will allow testing of notifications, growth tracking, and community features, making sure the app genuinely supports learning and keeps users engaged.

3. Test the system as a whole: Once the full system is assembled, including the frame, growing tray, LED lighting, moisture sensor, and app, carry out comprehensive testing. This will check how all parts work together, whether the moisture sensor feedback is clear, and if beginners can successfully grow seeds and seedlings.

4. Use iterative feedback: Collect continuous feedback from users throughout these tests. Adjustments to the frame, tray, sensors, or app interface can then be made to improve usability, learning support, and overall user experience.

5. For the further development of the app, it would be a great idea to introduce different user levels. For example, are you a complete beginner, or someone who already has some knowledge but lacks practical experience? This way, beginners can stay engaged with the app for longer, and the product becomes appealing to an even wider audience.

6. It would also be useful to include a Frequently Asked Questions (FAQ) section in the app. This would allow us to tackle common questions proactively and provide immediate clarity. This section could be combined with instructional videos, featuring Simon, for instance, to provide clear and engaging explanations.

Following these steps will help ensure that the Smart Growing System is not just technically solid, but also easy and enjoyable to use, while remaining a viable and sustainable solution for beginners over the long term.

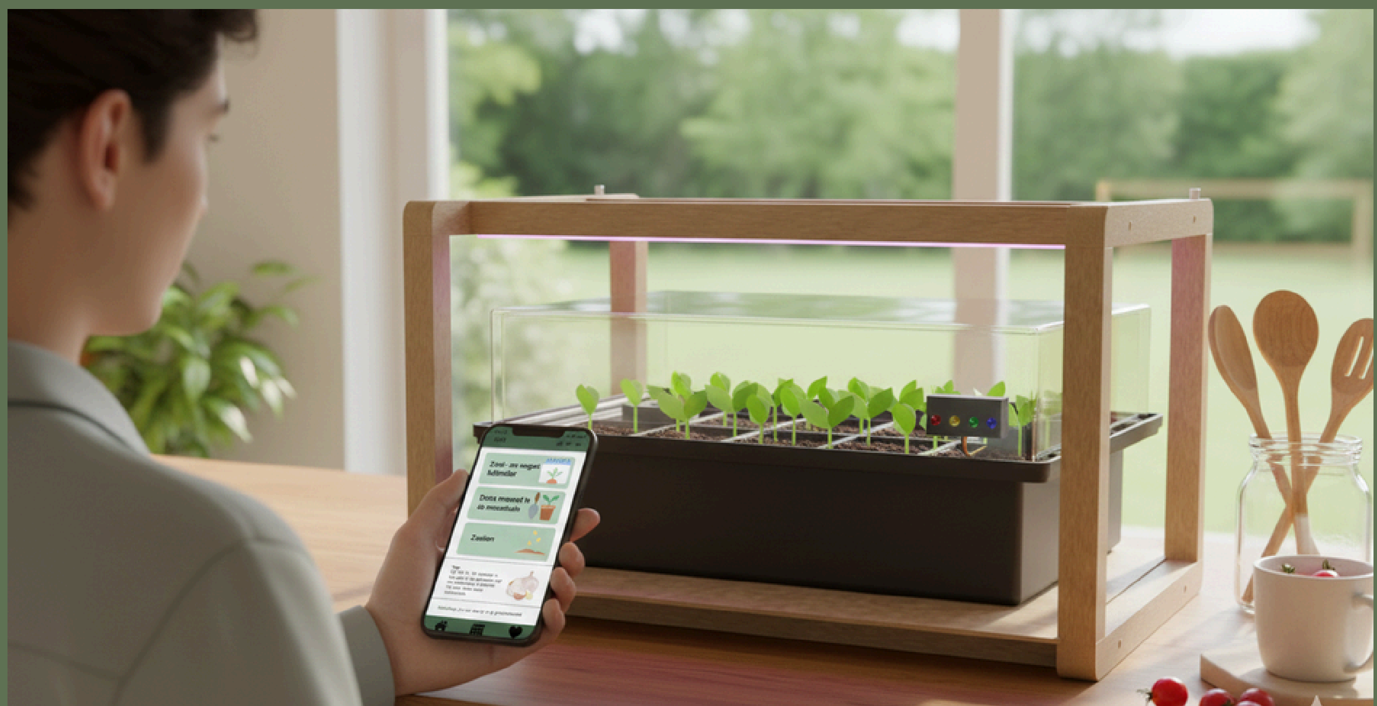
CONCLUSION

The Smart Growing System provides a well-considered solution to the challenges that beginner indoor gardeners often face: lack of knowledge and limited space. By combining a modular, compact, and adjustable physical system with a supporting app, the product makes gardening accessible, educational, and enjoyable. Users can actively learn by sowing and caring for plants themselves, while the system supports them with practical tools such as LED lighting, a moisture sensor, and clear step-by-step guidance in the app.

The design is both feasible and implementable: the materials (pinewood, Birch, and PP) and production methods (thermoforming and injection moulding) ensure durability, lightweight construction, functionality, and costefficiency, with an estimated production cost of approximately €47 per unit. This makes the system more affordable compared to many existing smart growing systems while maintaining quality and reliability.

Furthermore, the Smart Growing System creates new value for users and society. It encourages active engagement with the plant growth process, increases knowledge about food and sustainability, and promotes a healthier and more environmentally conscious lifestyle. By combining education, ease of use, and sustainability, the system goes beyond existing solutions, offering a meaningful and accessible experience for beginner indoor gardeners.

In short, the project demonstrates that a smart, modular, and affordable indoor growing system can be not only functional but also educational, sustainable, and enjoyable. It serves as a concrete example of how innovation in home gardening can bridge technology, learning, and a connection with nature.



REFLECTION

With this thesis, I finalize my Master's studies in Integrated Product Design at TU Delft. During my Bachelor's at TU Delft, I was not always equally enthusiastic about the program and the projects I worked on. I often found myself losing interest quickly, simply because the projects did not fully suit me. At times, I questioned whether this was the right field of study for me and whether I wanted to continue. Nevertheless, I decided to continue and give it another chance during the Master's in Integrated Product Design. This thesis has made me realize that designing can truly be enjoyable when the subject genuinely interests you, and I am very happy to have discovered that.

Before starting this project, I found it quite difficult to choose a topic for my thesis. There were several projects available through TU Delft, but none of them really felt right to me. During this period, while searching for a suitable topic, I spent a lot of time working in my vegetable garden. It was the first year that I had enough space to really develop it and grow a variety of crops. I noticed that this gave me a great deal of energy, and I wanted to do something with that enthusiasm. It all started when I began pre-sowing my seeds and realized I did not have enough space on my windowsill. I remember thinking, "Why has a designer never come up with a solution for this?" That moment made me realize I could combine my passion for vegetable gardening with my graduation project.

When I started this project, I had a clear idea of what I wanted to research and how I wanted to approach it. I had many ideas and began with great motivation. However, once I started the research phase, I realized how much information exists on a wide range of gardening-related topics. At some point, it became difficult for me to distinguish what was truly relevant to my project and what was simply interesting from a gardener's perspective. My supervisors supported me greatly during this process and helped me maintain focus.

I also greatly enjoyed collaborating with Simon. Although he has limited experience with design and the design process itself, he has extensive knowledge of vegetable gardening and the market surrounding it. Simon was able to help me when I struggled with making decisions. I was not designing for him as a client; instead, it felt like we developed the design together as a team.

In my learning goals, I stated that I wanted to spend more time experimenting with iterations and actually making a product. During previous projects in this study, there was often little time left for iteration and prototyping, as these phases usually took place at the end and were sometimes reduced to recommendations rather than fully explored. During this project, I was finally able to focus on iterating different components, 3D printing, creating SolidWorks models, and working hands-on. I gained a lot of energy from making something tangible again, rather than developing a concept that never fully materializes.

In addition to learning more about 3D modeling, I also learned a great deal about vegetable gardening itself. Although I already had some knowledge, there were many new things I discovered along the way. I also learned a lot from working with Simon and my supervisors, Adrie and Jotte. I realized that everyone brings a different perspective to situations, which made the process especially valuable and enjoyable.

Overall, I am very happy with how this project developed. There were moments when working individually was challenging, as the responsibility ultimately lies with yourself, but this is also where much learning takes place. I am grateful for the enjoyable collaboration and proud of the product that resulted from this project.
It feels like my passion for design has blossomed again! I am already looking forward to using it myself in the upcoming gardening season :)

REFERENCES

AMAZON.NL . (N.D.) 5PCS GROW BOX,GROW BOWL FOR PLANTS,MINI GREENHOUSE GROW SET WITH RAISED LID,SEEDLING STARTER WITH FULL SPECTRUM PLANT LIGHTS,10 LABELS 2 TOOLS. HTTPS://WWW.AMAZON.NL/DP/B0C1BW7V7T/REF=SYN_SD_ONSITE_DESKTOP_0?IE=UTF8&PD_RD_PLHDR=T&AREF=EPO1SGVDXD&TH=1

AMERICAN BRIGHT. (2024). ECO-FRIENDLY AND EFFICIENT: THE RISE OF LED HORTICULTURAL LIGHTING IN MODERN FARMING TECHNOLOGY. RETRIEVED OCTOBER 24, 2025, FROM HTTPS://WWW.AMERICANBRIGHTLED.COM/ECO-FRIENDLY-AND-EFFICIENT-THE-RISE-OF-LED-HORTICULTURAL-LIGHTING-IN-MODERN-FARMING-TECHNOLOGY/

AVONTS, D., KEUNE, H., & REMMEN, R. (2023). NATUUR OP DOKTERSVOORSCHRIFT: HOE BUITEN ZIJN ONS GEZOND HOUDT. LANNOO MEULENHOFF-BELGIUM.

BAKKER, J. VAN DER MOOREN, F.BOONSTRA, H.J. (2022, SEPTEMBER 11). 11. BUITENGEBRUIK. CENTRAAL BUREAU VOOR DE STATISTIEK. HTTPS://WWW.CBS.NL/NL-NL/LONGREAD/AANVULLENDE-STATISTISCHE-DIENSTEN/2022/WATERGEBRUIK-THUIS--WGT---2021/11-BUITENGEBRUIK?

BOSCH, J. S. (2015). DAGLICHTTOETREDING, BEREKENINGEN CONFORM DE NEN 2057:2011, EEN INLEIDING. HTTPS://KLIMAPEDIA.NL/WP-CONTENT/UPLOADS/2016/10/DAGLICHTTOETREDING-V4.0.PDF

BODEMVOEDSELWEB - BODEMWERELD. (2023, OCTOBER 12). BODEMWERELD. HTTPS://BODEMWERELD.NL/BODEMVOEDSELWEB-BODEMWERELD/

CBS (2025, JUNE 5). BEWOONDE WONINGEN; KENMERKEN WONING EN HUISHOUDEN, REGIO, 31 DECEMBER. CBS STATLINE. RETRIEVED SEPTEMBER 22, 2025, FROM HTTPS://OPENDATA.CBS.NL/#/CBS/NL/DATASET/86065NED/TABLE?DEFAULTVIEW

CHANG, C. C., LIN, B. B., FENG, X., ANDERSSON, E., GARDNER, J., & ASTELL-BURT, T. (2024). A LOWER CONNECTION TO NATURE IS RELATED TO LOWER MENTAL HEALTH BENEFITS FROM NATURE CONTACT. SCIENTIFIC REPORTS, 14(1), 6705.

CUSTOMPARTNET (2023).PROCESSES - POLYMER THERMOFORMING. HTTPS://WWW.CUSTOMPARTNET.COM/LIBRARY/THERMOFORMING

DESRANI, A., RITONGA, A. W., & LUBIS, M. (2024). LEARNING BY DOING: A TEACHING PARADIGM FOR ACTIVE LEARNING IN ISLAMIC HIGH SCHOOL. JOURNAL OF EDUCATION AND E-LEARNING RESEARCH, 10(4), 793-799.
ZEWIDE, I. (2021). REVIEW PAPER ON EFFECT OF MICRONUTRIENTS FOR CROP PRODUCTION.

DIRT CONNECTIONS. (2021, DECEMBER 15). WHAT IS LOAM SOIL AND WHAT IS IT USED FOR? DIRT CONNECTIONS. RETRIEVED SEPTEMBER 25, 2025, FROM HTTPS://WWW.DIRTCONNECTIONS.COM/WHAT-IS-LOAM-SOIL-AND-WHAT-IS-IT-USED-FOR/
DONOGHUE, G. M., & HATTIE, J. A. (2021, MARCH). A META-ANALYSIS OF TEN LEARNING TECHNIQUES. IN FRONTIERS IN EDUCATION (VOL. 6, P. 581216). FRONTIERS.

EDWARDS, J. R., DE ROOS, A. J., HAMPO, C. C., HUANG, W., LINCOLN, E., HOQUE, S., & SCHINASI, L. H. (2025). RESIDENTIAL INDOOR TEMPERATURES AND HEALTH: A SCOPING REVIEW OF OBSERVATIONAL STUDIES. SCIENCE OF THE TOTAL ENVIRONMENT, 979, 179377.

GAISEANU, F. (2022). INFORMATION IN PLANTS: THE INFORMATIONAL MODEL OF THE PLANT CELLS AND PLANT STRUCTURES. CELL BIOLOGY, 10(1), 31-40.

GROEN, ELIZABETH. (2025, JUNE 4). KOM MOESTUINIEREN IN DE BUURTTUIN VAN ELISABETH GROEN. ELISABETH GROEN. HTTPS://WWW.ELISABETHGROEN.NL/PROEFLAPJES/

HARALDSSON, K., GÖRANSON, M., & LINDGREN, E. C. (2024). "IT IS EASIER TO LEARN WHEN YOU ARE OUT": AN ETHNOGRAPHIC STUDY OF TEACHING SCIENCE SUBJECTS THROUGH OUTDOOR LEARNING AT COMPULSORY SCHOOL. JOURNAL OF OUTDOOR AND ENVIRONMENTAL EDUCATION, 1-16.

HILL, J. (2025, JUNE 30). 5 TRENDS SHAPING HYDROPONICS IN 2025 | URBAN GARDENING GUIDE. URBAN HOUSE GARDEN. HTTPS://URBANHOUSEANDGARDEN.COM/5-TRENDS-SHAPING-HYDROPONICS-IN-2025/

HUDELSON, B (2024). POWDERY MILDEW – VEGETABLES. RETRIEVED ON SEPTEMBER 4, 2025 FROM:HTTPS://HORT.EXTENSION.WISC.EDU/ARTICLES/POWDERY-MILDEW-VEGETABLES/

HUNDREDWORRIES. (2025). WINDOW SILL HEIGHT FROM THE FLOOR IN A PRIVATE HOUSE, APARTMENT AND BALCONY: STANDARDS - SETAFI. HUNDREDWORRIES. RETRIEVED SEPTEMBER 22, 2025, FROM HTTPS://HUNDRED-WORRIES.COM/EN/ADVICES/27422

JOHNSON, V. J., & MIRZA, A. (2020). ROLE OF MACRO AND MICRONUTRIENTS IN THE GROWTH AND DEVELOPMENT OF PLANTS. INT. J. CURR. MICROBIOL. APPL. SCI, 9, 576-587.

KENNISCENTRUM VAN DE OVERHEID. (N.D.) DAGLICHTTOETREDING: REGELS BIJ NIEUWBOUW (NEN-EN 17037). INFORMATIEPUNT LEEFOMGEVING. RETRIEVED SEPTEMBER 22, 2025, FROM HTTPS://IPLO.NL/REGELGEVING/REGELS-VOOR-ACTIVITEITEN/TECHNISCHE-BOUWACTIVITEIT/NIEUWBOUW/RIJKSREGELS/DAGLICHTTOETREDING-NEN-17037/

KLUITER, H. (2025, AUGUST 7). ZO COMBINEER JE POTTEN, BAKKEN EN PLANTEN TOT JE DROOMTUIN. GARDENERS WORLD. HTTPS://WWW.GARDENERSWORLDMAGAZINE.NL/INSPIRATIE/TUINIEREN-IN-POTTEN/

KOOMEN, J. (2025). THUIS IN DE MOESTUIN: MAAK VAN IEDERE VIERKANTE METER RONDOM JE HUIS EEN EETBAAR PARADIJS. NIJGH ATELIER.

KWAK, S., & CHOI, K. (2025). VISUAL PERCEPTIONS OF WOOD-INTEGRATED MATERIAL COMBINATIONS: EFFECTS ON PSYCHOLOGICAL AND PHYSIOLOGICAL RESPONSES. JOURNAL OF WOOD SCIENCE, 71(1), 20.

LAWNSEEDS. (2025, MAY 14). SILT SOIL FOR YOUR GARDEN OR LAWN. LAWN SEEDS. HTTPS://LAWN-SEEDS.COM/TIPS/2024/10/30/SILT-SOIL-FOR-YOUR-GARDEN-OR-LAWN/

LI, M. W., & GENDRON, J. M. (2025). EXPLORING THE METABOLIC DAYLENGTH MEASUREMENT SYSTEM: IMPLICATIONS FOR PHOTOPERIODIC GROWTH. NEW PHYTOLOGIST, 245(2), 503-509.

LIU, J., & VAN IERSEL, M. W. (2021). PHOTOSYNTHETIC PHYSIOLOGY OF BLUE, GREEN, AND RED LIGHT: LIGHT INTENSITY EFFECTS AND UNDERLYING MECHANISMS. FRONTIERS IN PLANT SCIENCE, 12, 619987.

MANIPPA, V., & TOMMASI, L. (2023). THE SHAPE OF YOU: DO INDIVIDUALS ASSOCIATE PARTICULAR GEOMETRIC SHAPES WITH IDENTITY?. CURRENT PSYCHOLOGY, 42(12), 10042-10052.

MASLEN, S. (2025, MAY 8). WORKING WITH CLAY SOIL. TURF ONLINE. HTTPS://WWW.TURFONLINE.CO.UK/BLOG/WORKING-WITH-CLAY-SOIL/?SRSLTID=AFMBOOODFL-HHP5F_C0BANAI8NOIE1NDNWFSVTAF_MJO7SMLC_KTELLZ

MERA, Y., RODRÍGUEZ, G., & MARIN-GARCIA, E. (2022). UNRAVELING THE BENEFITS OF EXPERIENCING ERRORS DURING LEARNING: DEFINITION, MODULATING FACTORS, AND EXPLANATORY THEORIES. PSYCHONOMIC BULLETIN & REVIEW, 29(3), 753-765.

MIJNVERTICALETUIN. (2023, JULY 10). VERTICALE KRUIDENTUIN BUITEN | VOOR BALKON, MUUR OF SCHUTTING. MIJN VERTICALE TUIN. HTTPS://MIJNVERTICALETUIN.NL/VERTICALE-KRUIDENTUIN-BUITEN/

MINISTERIE VAN BINNENLANDSE ZAKEN EN KONINKRIJKSRELATIES. (2021).WONEN LANGS DE MEETLAT: RESULTATEN VAN HET WOONONDERZOEK NEDERLAND 2021. IN. RETRIEVED SEPTEMBER 22, 2025, FROM HTTPS://WWW.VOLKSHUISVESTINGNEDERLAND.NL/DOCUMENTEN/PUBLICATIES/2022/06/08/KERNPUBLICATIE-VAN-HET-WOON2021-ONDERZOEK

NEDERLANDSE VOEDSEL EN WARENAUTORITEIT, NVWA.(2025). PLANTENZIEKTEN EN PLAGEN HERKENNEN. PLANTENZIEKTEN EN PLAGEN | NVWA. HTTPS://WWW.NVWA.NL/ONDERWERPEN/PLANTENZIEKTEN-EN-PLAGEN/PLANTENZIEKTEN-EN-PLAGEN-HERKENNEN

NIELSEN, L. (2024, SEPTEMBER 16). HOW TO AMEND AND IMPROVE SANDY SOIL. EPIC GARDENING. HTTPS://WWW.EPICGARDENING.COM/SANDY-SOIL/

PALUMBO, L., RUTA, N., & BERTAMINI, M. (2015). COMPARING ANGULAR AND CURVED SHAPES IN TERMS OF IMPLICIT ASSOCIATIONS AND APPROACH/AVOIDANCE RESPONSES. PLOS ONE, 10(10), E0140043.

PHOODFARM (N.D.). COMMUNITY FARMER PICKING GARDEN SUBSCRIPTION HTTPS://MEMBER.PHOODFARM.ORG/EN/COMMUNITY-FARMER-PLUKTUIN-ABONNEMENT/

PHOODFARM (N.D.). COMMUNITY FARMER PICKING GARDEN SUBSCRIPTION HTTPS://MEMBER.PHOODFARM.ORG/EN/COMMUNITY-FARMER-PLUKTUIN-ABONNEMENT/

PLUKKERS. (2025, MARCH 3). PROPAGATORS, WARMTEMATJES EN GROEILAMPEN | WAT HEB JE ECHT NODIG?🌱 [VIDEO]. YOUTUBE. HTTPS://WWW.YOUTUBE.COM/WATCH?V=5YPZYVX6X6Y

PLUKKERS. (2025, APRIL 15). ZAAIEN VOOR BEGINNERS | TOMAAT, PAPRIKA, KOMKOMMER EN ANDERE GROENTEN STARTEN [VIDEO]. YOUTUBE. HTTPS://WWW.YOUTUBE.COM/WATCH?V=VUUG0J0O3NY

RICHARDSON, M., PASSMORE, H. A., LUMBER, R., THOMAS, R., & HUNT, A. (2021). MOMENTS, NOT MINUTES: THE NATURE-WELLBEING RELATIONSHIP. INTERNATIONAL JOURNAL OF WELLBEING, 11(1).

RITTGARN, A. (2023). IDENTIFYING A CONSUMER-PRODUCER AGRICULTURAL KNOWLEDGE GAP.

SCHADBILD (JANUARY 30, 2025) VIREN (POTATO VIRUS PVY), POTATO LEAFROLL VIRUS PLRV) AN KARTOFFEL (SOLANUM TUBEROSUM) RETRIEVED ON SEPTEMBER 8, 2025, FROM: . SCHADBILDER. HTTPS://WWW.SCHADBILD.COM/GEM%C3%BCSE/KARTOFFEL/VIRUS/

TOOLCRAFT PLASTICS (N.D.) THE INJECTION MOULDING PROCESS - CYCLE EXPLAINED. HTTPS://WWW.TOOLCRAFT.CO.UK/PLASTIC-INJECTION-MOULDING/ADVICE/HELP-INJECTION-MOULDING-PROCESS.HTM

TUINARTIKELEN.NU. (2025, FEBRUARY 18). DE TUINTRENDS VAN 2025. HTTPS://WWW.TUINARTIKELEN.NU/BLOGS/TUIN/TUINTRENDS-VAN-2025-WAT-JE-KUNT-VERWACHTEN/

VAN DER VOORDT, T., BAKKER, I., & DE BOON, J. (2017). COLOR PREFERENCES FOR FOUR DIFFERENT TYPES OF SPACES. FACILITIES, 35(3/4), 155-169.

WU, W., CHEN, L., LIANG, R., HUANG, S., LI, X., HUANG, B., ... & ZHU, H. (2025). THE ROLE OF LIGHT IN REGULATING PLANT GROWTH, DEVELOPMENT AND SUGAR METABOLISM: A REVIEW. FRONTIERS IN PLANT SCIENCE, 15, 1507628.

XU, J., LIN, T., WANG, Y., JIANG, W., LI, Q., LU, T., ... & YU, H. (2024). HOME FOOD GARDENING IN MODERN CITIES: ADVANCES, ISSUES, AND FUTURE PERSPECTIVES. FRONTIERS IN SUSTAINABLE FOOD SYSTEMS, 8, 1391732.

ZEWIDE, I. (2021). REVIEW PAPER ON EFFECT OF MICRONUTRIENTS FOR CROP PRODUCTION.

APPENDIX

APPENDIX 1: PROJECT BRIEF

TUDelft

DESIGN FOR our future

IDE Master Graduation Project

Projectteam,procedural checks and PersonalProject Brief

In this document the agreements made between student and supervisory team about the student's IDE Master Graduation Project are set out. This document may also include involvement of an external client, however does not cover any legal matters student and client (might) agree upon. Next to that, this document facilitates the required procedural checks:

- Student defines the team, what the student is going to do/deliver and how that will come about
- Chair of the supervisory team signs, to formally approve the project's setup / Project brief
- SSC E&SA (Shared Service Centre, Education & Student Affairs) report on the student's registration and study progress
- IDE's Board of Examiners confirms the proposed supervisory team on their eligibility, and whether the student is allowed to start the Graduation Project

STUDENT DATA&MASTERPROGRAMME
Complete all fields and indicate which master(s) you are in

Family name Baart

Initials I

Given name Iris

Student number [redacted]

IDE master(s) IPD ✓ Dfl SPD

2nd non-IDE master

Individual programme *(date of approval)*

Medisign

HPM

SUPERVISORYTEAM
Fill in he required information of supervisory team members. If applicable, company mentor is added as 2nd mentor

Chair	Jotte deKoning	dept./section	
mentor	Adrie Kooijman	dept./section	
2nd mentor			
client:	Simon Eurlings		
city:	Heerlen	country:	Netherlands
optional comments			

! Ensure a heterogeneous team. In case you wish to include team members from the same section, explain why.

! Chair should request the IDE Board of Examiners for approval when a non-IDE mentor is proposed. Include CV and motivation letter.

! 2nd mentor only applies when a client is involved.

APPROVAL OF CHAIR on PROJECT PROPOSAL / PROJECT BRIEF -> to be filled in **by the Chair** of the supervisory team

Sign for approval (Chair)

Name Date Signature

TUDelft

DESIGN FOR our future

Personal Project Brief – IDE Master Graduation Project

Name student Iris Baart **Student number** [redacted]

PROJECTTITLE,INTRODUCTION,PROBLEMDEFINITIONand ASSIGNMENT
Complete all fields, keep information clear, specific and concise

Project title Smart growing system

Please state the title of your graduation project (above). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

Introduction

Describe the context of your project here; What is the domain in which your project takes place? Who are the main stakeholders and what interests are at stake? Describe the opportunities (and limitations) in this domain to better serve the stakeholder interests. (max 250 words)

This project is situated in the context of (indoor) home gardening, focused on beginner gardeners. As I am also a beginner gardener, I faced two major challenges when sowing: limited indoor space and a lack of knowledge about plant care. Due to urbanization, many people live in smaller spaces like—apartments or compact houses—leaving little or no space for outdoor gardening. This reduction in available space limits knowledge and direct interaction with the food-growing process (Xu et al., 2024).

The main stakeholders consists of beginner gardeners who want to grow vegetables, regardless of their living space (apartments, small houses or rural houses). A common situation is that windowsills quickly fill up with seed trays, while questions arise about watering, light, and next steps in the plants growth cycle.

This project responds to the need for a space-efficient and supportive (indoor) growing solution, by combining a smart growing system with useful information for the beginner gardener. Opportunities lie in educating and empowering users through meaningful interaction with both the physical and digital components. The aim is not just automation, but engagement and confidence-building for beginner gardeners. The challenge is to design a system that is intelligent and helpful, but not overly complex or expensive, making it accessible, educational, and enjoyable to use across a range of living environments.

→ *space available for images / figures on next page*

DESIGN FOR our future

TUDelft

Personal Project Brief – IDE Master Graduation Project

Problem Definition

What problem do you want to solve in the context described in the introduction, and within the available time frame of 100 working days? (= Master Graduation Project of 30 EC). What opportunities do you see to create added value for the described stakeholders? Substantiate your choice.
(max 200 words)

Urbanization and modern lifestyles have created a growing disconnect between people and the origins of their food (Xu et al., 2024). Many individuals, no longer know how vegetables are grown, how much time and care this requires, or how seasonal cycles influence cultivation. This can result in misconceptions about the agriculture industry, poor dietary choices, and increased food waste (Rittgarn, 2023).

The (over)use of the mobile phone is related to less nature contact, which is linked to lower subjective well-being and psychological well-being (Wang, 2023). Gardening promotes healthier eating, social interaction, and mental well-being, even boosting serotonin levels in the brain for a mood-enhancing effect (Avonts et al., 2023). In addition, home gardening supports sustainable living by providing local, fresh food, reducing packaging waste, and lowering the environmental impact of food production at a small scale.

Beginner gardeners who want to start growing their own food face a steep learning curve. They often lack knowledge about plant care, growth stages, and harvesting (Xu et al., 2024). Without accessible guidance, the process can feel overwhelming and discourage long-term engagement.

Assignment

This is the most important part of the project brief because it will give a clear direction of what you are heading for. Formulate an assignment to yourself regarding what you expect to deliver as result at the end of your project. (1 sentence)
As you graduate as an industrial design engineer, your assignment will start with a verb (Design/Investigate/Validate/Create), and you may use the green text format*:*

Design a smart growing system (prototype) to support and guide the indoor food-growing experience for beginner home gardeners in the context of limited indoor space and a growing interest in sustainable living.

Then explain your project approach to carrying out your graduation project and what research and design methods you plan to use to generate your design solution (max 150 words)

-Desk/literature Research
-User observations in vegetable gardens.
-Interview (beginner) gardeners to see what they struggle with (and implement this in the concept) --> User journey map of how they work and what they struggle with, visualizing key moments and identify design opportunities.
-brainstorm about concepts, Co-design with other students, make drawings, make prototypes and see what does(not) work, rapid prototyping , later experience prototypes with user tests, measurements on environmental aspects (light, humidity) and technical aspects
-Connect smart growing system with information for the user.
-Deliverables: Master thesis, a physical product of the smart growing system, (a part) of the app which is connected to the growing system.

Project planning and key moments

To make visible how you plan to spend your time, you must make a planning for the full project. You are advised to use a Gantt chart format to show the different phases of your project, deliverables you have in mind, meetings and in-between deadlines. Keep in mind that all activities should fit within the given run time of 100 working days. Your planning should include a ***kick-off meeting***, ***mid-term evaluation meeting***, ***green light meeting*** *and* ***graduation ceremony***. *Please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any (for instance because of holidays or parallel course activities).*

Make sure to attach the full plan to this project brief.
The four key moment dates must be filled in below

Kick off meeting	28 Aug 2025
Mid-term evaluation	3 Nov 2025
Green light meeting	12 Jan 2025
Graduation ceremony	4 Feb 2025

In exceptional cases (part of) the Graduation Project may need to be scheduled part-time. Indicate here if such applies to your project

Part of project scheduled part-time	
For how many project weeks	
Number of project days per week	

Comments:

Motivation and personal ambitions

Explain why you wish to start this project, what competencies you want to prove or develop (e.g. competencies acquired in your MSc programme, electives, extra-curricular activities or other).

Optionally, describe whether you have some personal learning ambitions which you explicitly want to address in this project, on top of the learning objectives of the Graduation Project itself. You might think of e.g. acquiring in depth knowledge on a specific subject, broadening your competencies or experimenting with a specific tool or methodology. Personal learning ambitions are limited to a maximum number of five.
(200 words max)

-First of all, as I am a beginner gardener myself, I would love to learn more about gardening. I watch a lot of videos about gardening, but doing in depth research would teach me much more about plants, their needs and the possiblities with gardening.

-I also want to learn prototyping and actually make something that I am proud of and would use.

-I want to experiment with different prototypes and make different iterations. Doing this, I hope to learn more about 3D printing and maybe other possibilities to create a nice working prototype.

-I would love to learn more from my client and create something we are both proud of.

APPENDIX 2: GROUPS COLLECTED MATERIAL OF EXISTING GARDENING PRODUCTS

APPENDIX 3: INTERVIEWS EXPERTS

ERWIN EN LAURA

Achtergrond

1. Hoe lang heb je al een moestuin?

14 jaar (sinds 2011)

1. Wat was de belangrijkste reden om te beginnen met moestuinieren?

Erwin en Laura hebben een eigen bedrijf en zijn al veel bezig met voedings en gezondheid. Het avontuur is pas echt begonnen toen hun dochter in aanraking kwam met de schoolmoestuin. Ze proefde hier van en merkte dat het eten wat ze zelf konden verbouwen toch echt veel lekkerder was dan het eten uit de supermarkt.

Zij was hier heel enthousiast over en toen ze dit met een van haar klanten besprak, vertelde ze dat ze nog een plekje hadden in de moestuin. Vanuit hier zijn ze ook begonnen met hun eigen moestuin.

Motivatie

1. Wat vind je het leukste aan moestuinieren?

- Oogsten en direct eten, smaak is super goed, vers.
- Je eet meer van bepaalde dingen die je oogst, meer seizoensgebonden.
- Onderzoeken met nieuwe rassen, nieuwe dingen proberen en daarvan.
- Ontspanning, aards bezig zijn, nieuwschierigheid wat er uit een zaadje komt, groeiproces heel interessant, energie en voldoening van wat je zelf hebt.
- Kan er haar energie in kwijt. Ethousiast na een goede oogst.
- Contacten met de mensen daar bij het complex vind ik ook leuk.
- Geniet van connectie met de natuur.

2. Wat vind je het moeilijkste of meest frustrerende aspect?

- Veel bezig met onkruid wieden
- Zit veel tijd in
- Gebonden om op je gewassen te letten, zonde van je opbrengst als je er niet bent.
- Rommel van anderen bij de moestuin zelf.

3. Welke momenten in je moestuin geven je het meest voldoening?

Lekkere gerechten maken van de dingen die ik heb geoost, leuk als alles lukt.

Kennis en leerproces

1. Hoe heb je leren moestuinieren (boeken, internet, familie, cursussen, etc.)?

zus van Erwin die wist er veel vanaf dus daar hebben ze voornamelijk de basis geleerd. Samen zijn ze aan de slag gegaan.

Voor de rest hebben ze veel kennis gekrengen via via, Bij de moestuin komen ze geregeld mensen tegen en hier delen ze dan tips met elkaar. Ook door veel zelf dingen te proberen leren ze erg goed. Dan merk je al snel of iets wel of niet werkt en is ook een hele leuke manier van leren.

1. Welke vaardigheden vond je het moeilijkst om onder de knie te krijgen?

- wanneer ga je dingen zaaien, hoe verzorg je bepaalde planten? Deze informatie was in het begin vooral erg lastig omdat het erg veel is.

2. Als je iets nieuws wilt leren over moestuinieren, hoe doe je dat het liefst? (bijv. workshop, online video, mentor).

Ze weten al erg veel maar als ze nog eens wat nieuws willen leren dan zoeken ze dit op op het internet. Hier staat genoeg.

Praktische aanpak

1. Welke groenten, kruiden of planten kweek je het liefst en waarom?

- fruit leuk, tomaten-> leuk om het bij te kunnen houden. Erwin vindt het heerlijk om regelmatig in de tuin te lopen en alles goed bij te houden in de tuin. Zo kan hij even zijn energie kwijt.
- basilicum vind ik lekker dus leuk
- sla, is makkelijk maar vind ik wel heel lekker
- bloemen, uit eigen tuin is heel erg leuk om eigen boeketten van te maken
- dingen die snel groeien, niet te lang hoeven wachten.

2. Hoe plan je je moestuin (zaaien, planten, rotatie, bemesting)?

Wisselteelt, kijken wat we waar neerzetten. Per jaar kijken wat lekker is en dat zaaien en kijken wat ze graag willen zaaien.

1. Heb je tips of een truc/routines die voor jou altijd goed werken?

- blijven zoeken naar goeie methodes, bij bonen touwtjes tussen, klimmen ze mee naar boven.
- courgettes en pompoen bij elkaar, willen graag stikstof, die komen bij de bonen-> Bonen stikstof in de grond
- trio: bonen, mais , pompoen of courgette. Houden de grond neutraal.
- Zet dingen bij elkaar die mekaar versterken.

Ervaring en reflectie

1. Hoeveel tijd besteed je gemiddeld per week aan je moestuin?

- afhankelijk van het weer en de tijd van het jaar. Als dingen snel groeien dan is Erwin er vaker (5 dagen in de week als het druk is). Als het veel geregend heeft dan is hij er minder, omdat de planten heel simpel gewoon al genoeg wat hebben.
- 8u per week in de week heb je wel nodig als je redelijk wat grond hebt. Onkruid wieden duurt gewoon lang en moet je goed bij houden.

2. Wat zou je meegeven aan iemand die net begint met moestuinieren?

- snel resultaat hebben, keuzes van groentes die goed gaan, succes verzekerd.
- Zaai wat je lekker vindt.
- Niet te veel willen zaaien in 1x, houd er rekening mee dat groenten en fruit ruimte nodig hebben om goed te kunnen groeien. In het begin lijkt het weinig maar later in het seizoen merk je dat ze de ruimte nodig hebben.
- Zaden kopen rondom de kerst kopen, dan is het niet uitverkocht.
- keuzes maken. Je moet niet te groot willen beginnen. Begin klein, leer en breid daarna weer uit.

3. Zijn er dingen die je nog graag zou willen proberen of verbeteren in je moestuin?

- sojaboontjes
- zoete aardappel

Achtergrond

1. Hoe lang heb je al een moestuin?

5 jaar. Hij is begonnen tijdens corona.

1. Wat was de belangrijkste reden om te beginnen met moestuinieren?

Simon is begonnen met moestuinieren tijdens corona. Hij is voornamelijk begonnen uit verveling. 'Ik pakte een zakje broccoli zaadjes en strooide dit over een beetje grond heen'. Hij merkte dat het hem erg veel rust gaf om bezig te zijn met zijn handen en even weg van de mobiele wereld. Daarbij vond hij het erg leuk om snel verandering te zien:' Na een paar dagen groeit er al een plantje uit het zaadje wat je gezaaid hebt'.

Motivatie

1. Wat vind je het leukste aan moestuinieren?

Simon vindt het het leukste om even lekker bezig te zijn. Even het hoofd leeg maken en met je handen wroeten in de grond. Daarnaast is het buiten bezig zijn ook erg fijn.

Wat vind je het moeilijkste of meest frustrerende aspect?

- De bijkomst van plaagdieren (slakken en muizen). Je bent weken bezig geweest en hebt moeite gedaan om iets op te bouwen. Deze dieren komen langs en het is allemaal voor niks geweest.
- Het gevoel dat je alles goed hebt gedaan maar het toch niet lukt. Met het moestuinieren gaan dingen soms goed en soms fout. Je kan het precies hetzelfde doen, maar soms pakt dit gewoon anders uit.

1. Welke momenten in je moestuin geven je het meest voldoening?

- Het gevoel dat er iets gelukt is en je eigenlijk je eigen groente en fruit hebt verbouwd. Het echt gewoon zelf hebben gedaan en dat het lukt is erg leuk.

Kennis en leerproces

1. Hoe heb je leren moestuinieren (boeken, internet, familie, cursussen, etc.)?

- Ik ben vooral dingen zelf gaan proberen. Dan merk je zelf heel goed wat er wel en niet werkt.
- Informatie zoeken op het internet. Filmpjes hoe je dingen moet doen of info.
- Ook wat informatie uit boeken gehaald, vooral wat je per maand kan doen in de moestuin.

1. Zijn er bronnen of methodes die je erg behulpzaam vond?

- In het begin vooral boeken, maar van het internet ook veel informatie.

1. Als je iets nieuws wilt leren over moestuinieren, hoe doe je dat het liefst? (bijv. workshop, online video, mentor)

- Video kijken of boek lezen voordat je begint. Niet zomaar meer proberen. Vooral video's kunnen snel een beeld geven van wat je moet doen.

Praktische aanpak

1. Welke groenten, kruiden of planten kweek je het liefst en waarom?

- Pepers, broccoli. vooral eerst alles uitproberen en wat je lekker vindt.

2. Hoe plan je je moestuin (zaaien, planten, rotatie, bemesting)?

- Kijkt wat bij elkaar past. Zaden niet op dezelfde plek, elk jaar weer een andere plek. Maak eerst een planning van wat je wil doen.

Ervaring en reflectie

1. Hoeveel tijd besteed je gemiddeld per week aan je moestuin?

- Voorjaar minstens 2x in de week. Het liefst elke dag, maar hier is niet altijd tijd voor. Bij natte periodes ga ik vaak het meest, doordat er dan veel slakken in de moestuin te vinden zijn.

1. Zijn er fouten of mislukkingen waar je veel van geleerd hebt?

- Met zaaien dacht ik in het begin altijd, hoe meer ik zaai, hoe meer ik krijg. Dat was zeker anders want vaak krijg je gewoon minder. De afstanden tussen de planten zijn belangrijk zodat deze goed kunnen groeien.

1. Wat zou je meegeven aan iemand die net begint met moestuinieren?

- Klein beginnen , simpele gewassen (sla, rucola, prei, rode biet). Eerst succes en daarna experimenteren met moeilijkere dingen . Als je klein begint heb je automatisch ook minder onkruid. Vooral in het begin moet het gewoon leuk blijven.

2. Zijn er dingen die je nog graag zou willen proberen of verbeteren in je moestuin?

Asperges, een kas voor tropische dingen, meer ontdekken in wat je kan met je oogst, verwerken

Achtergrond

1. Hoe lang heb je al een moestuin?

Gerda is al 30 jaar al bezig met moestuinieren. Ze is begonnen met veel groente en daarna is ze ook veel fruit gaan kweken voor bijvoorbeeld wijn (druiven).

1. Wat was de belangrijkste reden om te beginnen met moestuinieren?

Een oom van haar wist al heel veel van moestuinieren. Omdat er bij het huis een grote tuin zat, heeft ze veel van haar oom geleerd om te gaan beginnen.

Motivatie

1. Wat vind je het leukste aan moestuinieren?

Het is lekker om in de tuin te werken en heerlijk buiten te zijn. Het is altijd stil in de tuin en ik kan hier echt mijn rust vinden.

Wat vind je het moeilijkste of meest frustrerende aspect?

Ik vind het het meest frustrerend als ik ergens mijn best voor doe en het dan niet lukt. Dit jaar heb ik weer geprobeerd boontjes te kweken en dit is helaas niet gelukt.

1. Welke momenten in je moestuin geven je het meest voldoening?

Als ik iets heb geplant en het lukt goed. Ik kan er echt van genieten als de moestuin er mooi bij staat en er zitten overal veel vruchten aan. Ook vind ik het dan erg leuk om alles te kunnen verwerken. Van tomaten maak ik graag sausjes en soep.

Kennis en leerproces

1. Hoe heb je leren moestuinieren (boeken, internet, familie, cursussen, etc.)?

Van oom geleerd, die vond de tuin leuk en heeft alle info doorgegeven. Als er iets mis ging dan zocht ik het ook nog weleens op in boeken, bijvoorbeeld met ziektes..

1. Zijn er bronnen of methodes die je erg behulpzaam vond?

Tegenwoordig kan ik via google veel dingen leren als ik iets nieuws wil leren. Toch leer ik zelf nog het best als ik zelf iets heb uitgeprobeerd.

1. Welke vaardigheden vond je het moeilijkst om onder de knie te krijgen?
   - Snoeien. Zonde om af te knippen. Lastig om alles netjes te houden. Ik vind dat zonde van de planten.
2. Als je iets nieuws wilt leren over moestuinieren, hoe doe je dat het liefst? (bijv. workshop, online video, mentor).

Ik leer het meeste van de mensen met wie ik over mijn moestuin praat. Soms lopen mensen langs die wat zeggen, waar ik wat van leer en soms heb ik vrienden/collega's waar ik weer wat van leer.

Praktische aanpak

1. Welke groenten, kruiden of planten kweek je het liefst en waarom?

Druiven vind ik heel leuk, kweken we voor de wijn

Tomaten vind ik ook erg leuk, lekker om te verwerken, lukt eigenlijk altijd.

Klein fruit, is erg makkelijk, bij snoeien, maar voor de rest niet veel aan doen.

1. Hoe plan je je moestuin (zaaien, planten, rotatie, bemesting)?
   - Onthouden waar ik dingen neer heb gezet, elk jaar zetten we het ongeveer op een andere plek.
2. Heb je tips of een truc/routines die voor jou altijd goed werken?
   - Voorkweken in een verwarmingsbak werkt erg goed.
   - Ik hou alles goed in de gaten. Ik kijk naar wat ze nodig hebben en daar steek ik energie in.
   - Water geven is heel erg belangrijk. Sproeien wel, maar niet meteen teveel.

Ervaring en reflectie

1. Hoeveel tijd besteed je gemiddeld per week aan je moestuin?

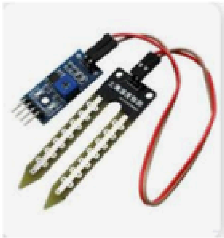
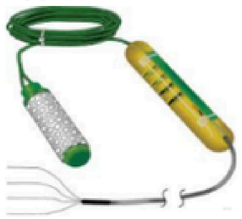
Elke dag loop ik er even doorheen. Water geven, goed in de gaten houden.

1. Zijn er fouten of mislukkingen waar je veel van geleerd hebt?
   - Dingen te dicht op elkaar zetten. Niet door hebben hoe groot die planten worden. Het liefst in het begin alles lekker dicht bij elkaar. Niet door hoe weinig ruimte ze eigenlijk gaan hebben om te groeien.
2. Wat zou je meegeven aan iemand die net begint met moestuinieren?
   - geniet ervan
   - lekker proberen. mislukken hoort erbij. volgend jaar weer opnieuw.
3. Wat werkt wel voor jou en wat juist niet?
   - goed in de gaten houden werkt bij mij heel goed. Je komt er snel achter als iets te weinig water heeft en kan snel ingrijpen op het moment dat je iets ziet wat niet klopt.

APPENDIX 4: QUESTIONNAIRE NOVEL GARDENERS

APPENDIX 5: MOISTURE SENSORS

Moisture sensors

Sensor Type	Working Principle	Suitability for Smart Grow Box
Resistive 	Measures electrical resistance between two probes.	Cheap and simple, but prone to corrosion.
Capacitive 	Detects changes in dielectric constant of moist soil.	Accurate, durable, ideal for indoor seed trays.
FDR / TDR 	Measures signal reflection or frequency response in soil.	Very precise, but too complex and expensive.
Gypsum Block 	Resistance changes as gypsum absorbs soil moisture.	Slow response, better for larger soil volumes.
Neutron / Radiometric 	Uses radiation to detect water content.	Not suitable for home use.
Standalone Meters 	Often resistive or capacitive handheld devices.	Convenient for quick household checks.

For a small indoor seed grow box, capacitive soil moisture sensors are the most suitable due to their accuracy, durability, and reliability in small soil volumes. Resistive probes are a cheaper alternative but less accurate and prone to corrosion.

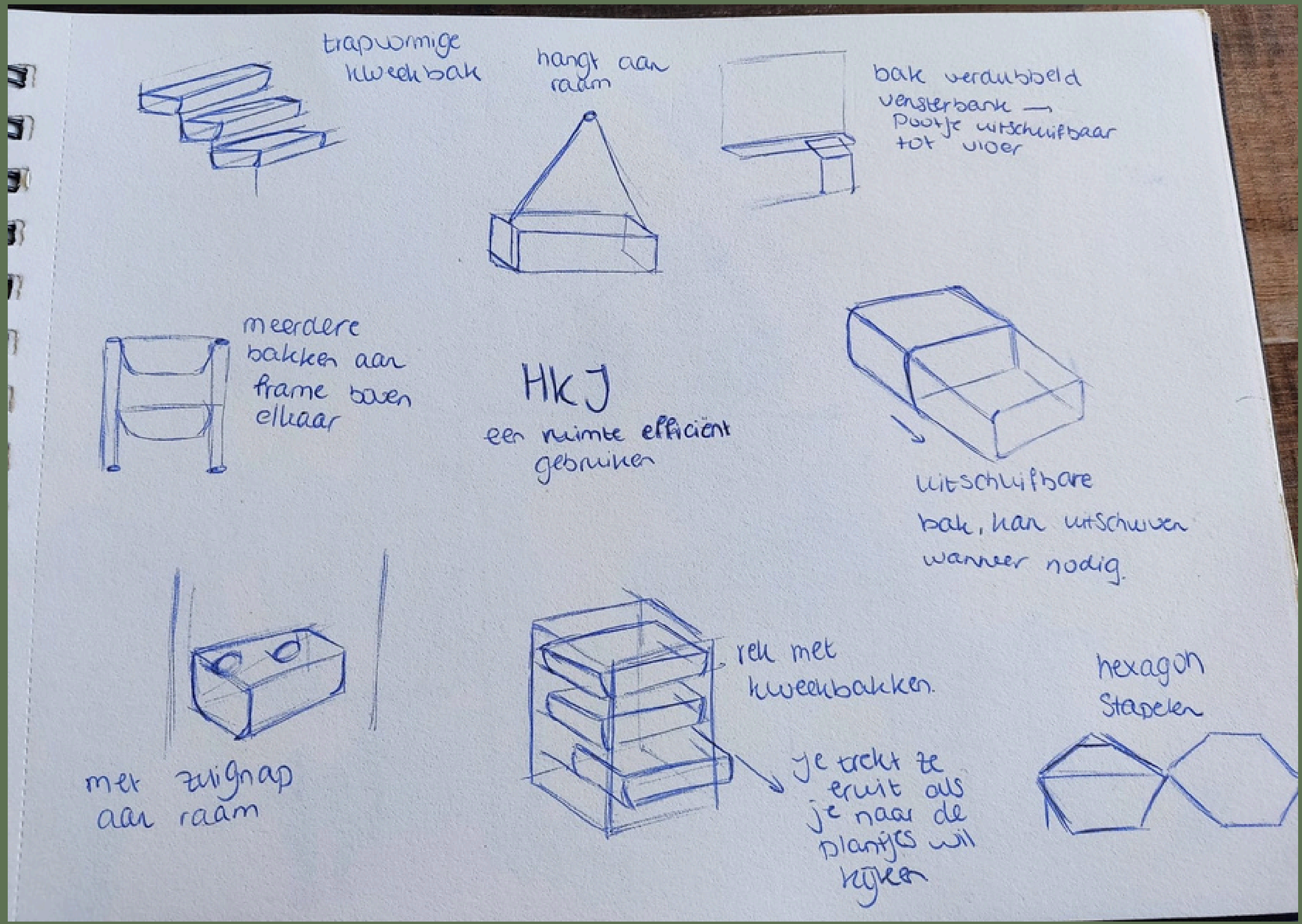
Optimal Moisture Conditions for Indoor Seedling Growth

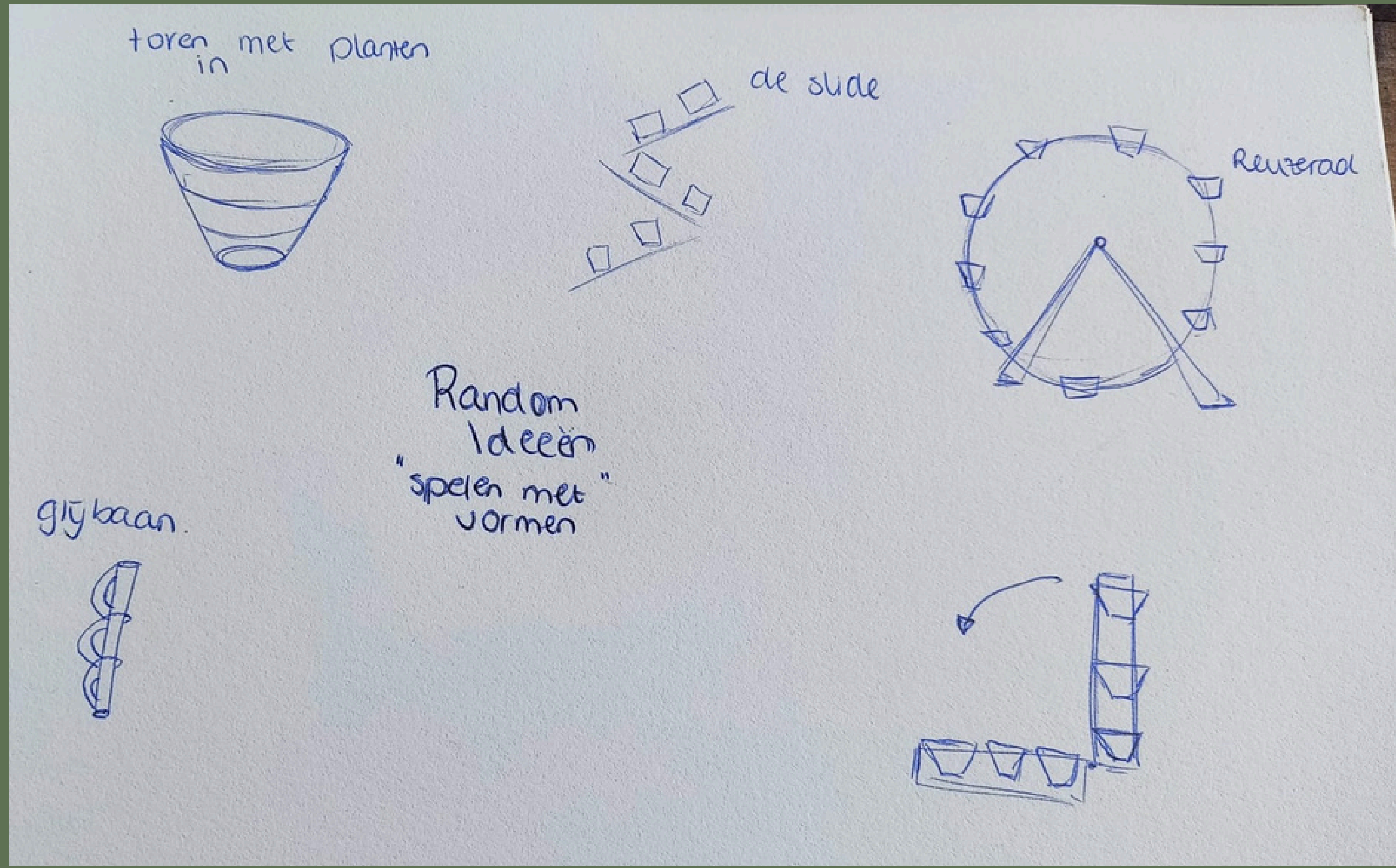
For successful indoor seedling growth, maintaining the right soil moisture is essential. Both too little and too much water can slow down germination and weaken plants. Soil moisture is measured as VWC (Volumetric Water Content), which shows how much of the soil volume is filled with water. For example, 25% VWC means that one quarter of the soil consists of water.

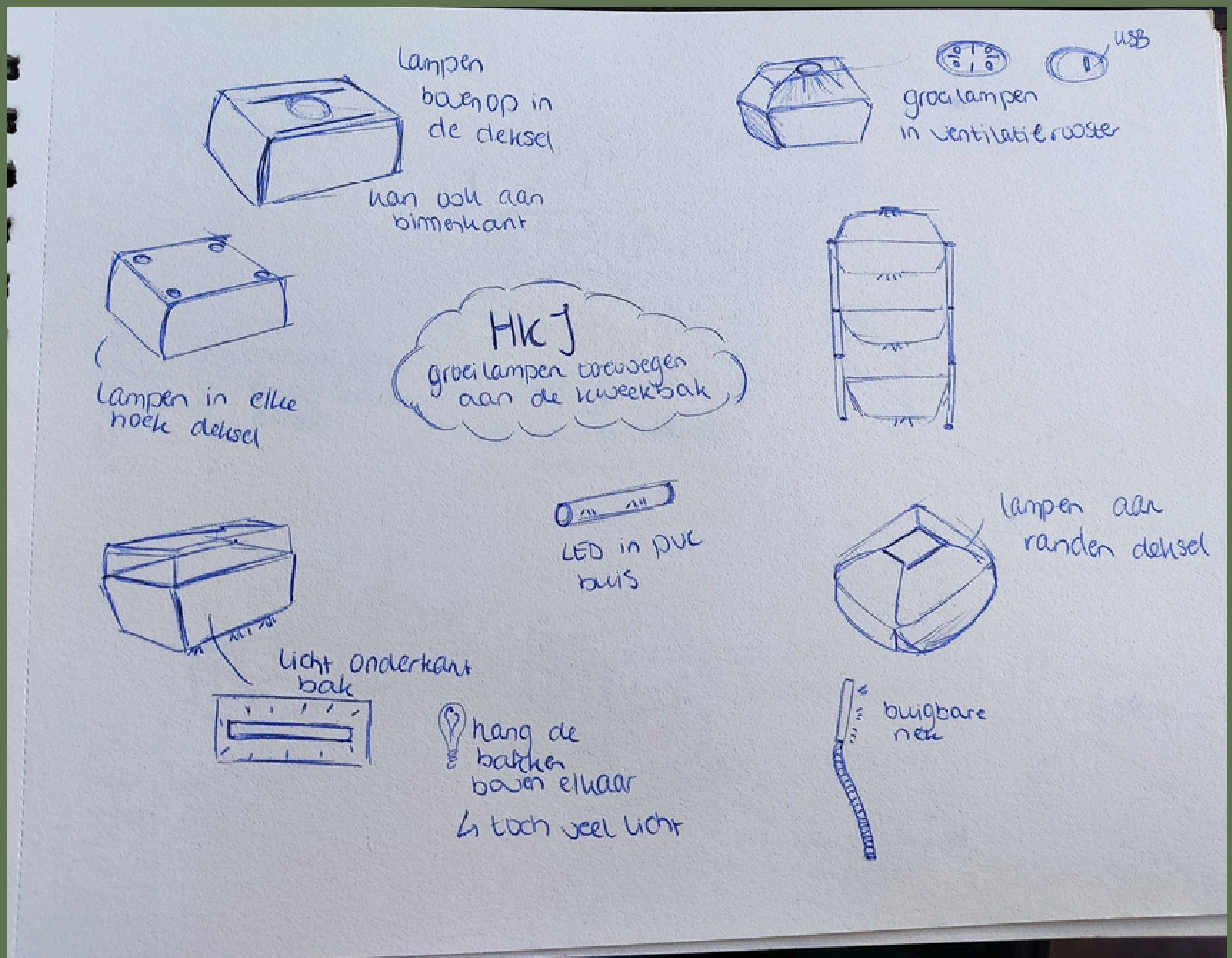
Studies have shown that seedlings grow best when moisture levels stay within a moderate range. Larson et al. (2016) found that roots developed best between 18–26% VWC, while Li et al. (2020) reported an ideal range of 23–28% VWC. Both studies found that too dry (<20%) or too wet (>30–33%) conditions reduce growth. According to Oklahoma State University Extension (2021), this roughly corresponds to “field capacity,” or soil that is moist but not waterlogged—typically 20–30% VWC.

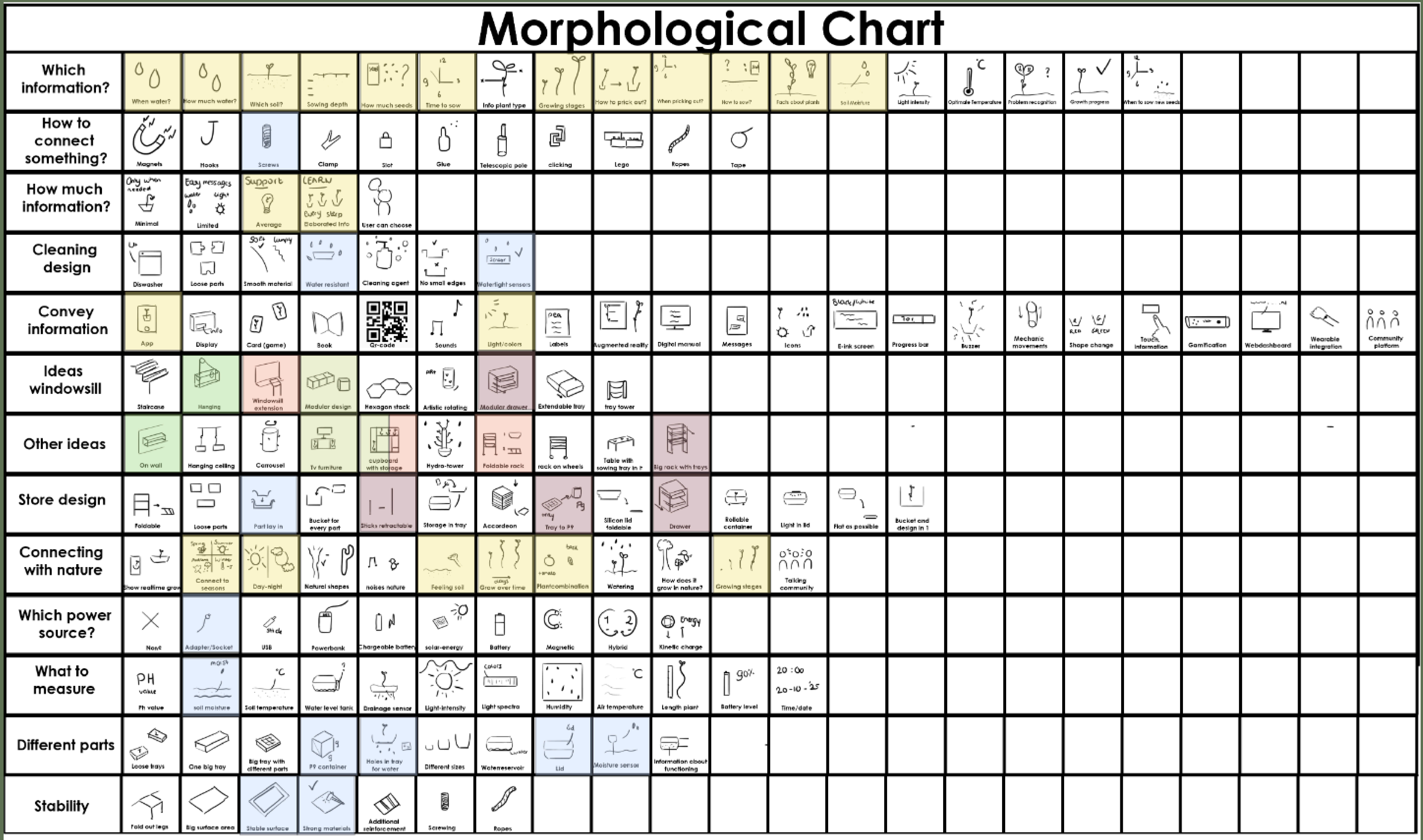
During germination, seeds need slightly more water—around 25–35% VWC—to start sprouting. For the later seedling stage, a range of 20–30% VWC is recommended. Values below 15% cause drought stress, while levels above 35–40% can lead to oxygen deficiency, mold, or root rot.

In summary, for a smart indoor growing system, the ideal moisture range is 25–35% VWC during germination and 20–30% VWC during seedling growth, with alerts when conditions move outside these limits.


trapvormige kweekbak
hangt aan raam
bak verdubbeld vensterbank — pootje uitschuifbaar tot vloer
meerdere bakken aan frame boven elkaar
HKJ
een ruimte efficiënt gebruiken
uitschuifbare bak, kan uitschuiven wanneer nodig.
met zuignap aan raam
rek met kweekbakken.
je trekt ze eruit als je naar de plantjes wil kijken
hexagon stapelen

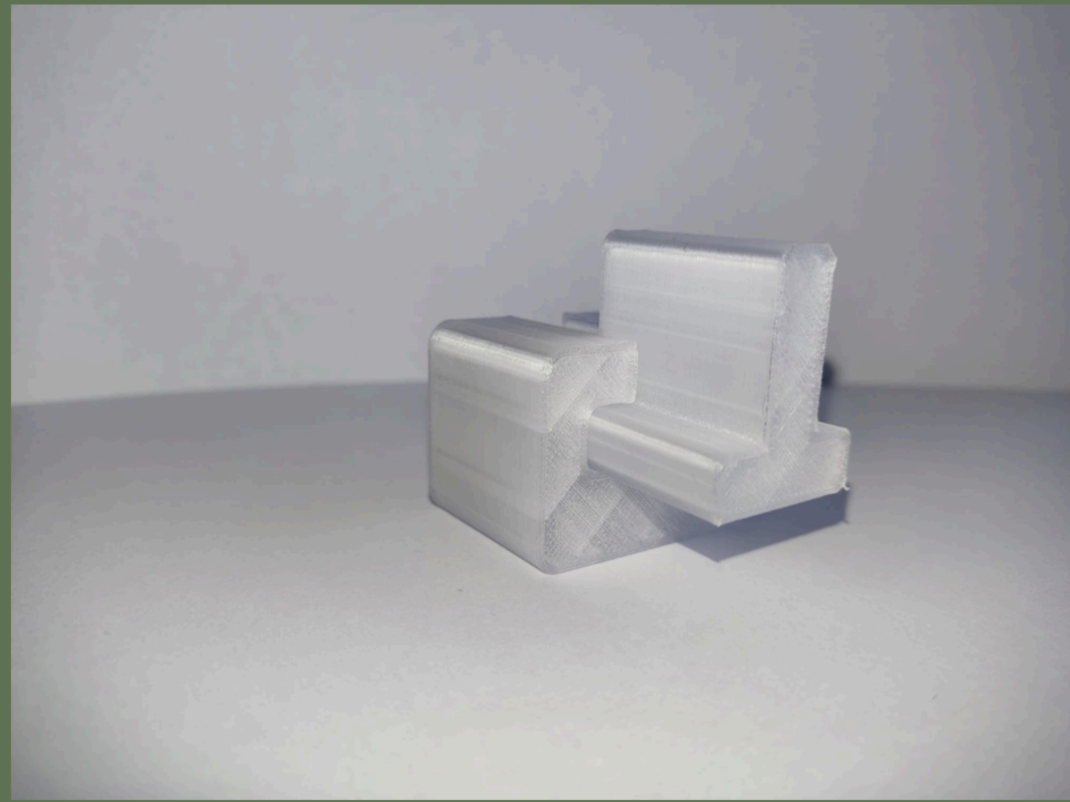

toren met planten in
de slide
Reuzerad
Random Ideeën
"spelen met vormen"
glijbaan.

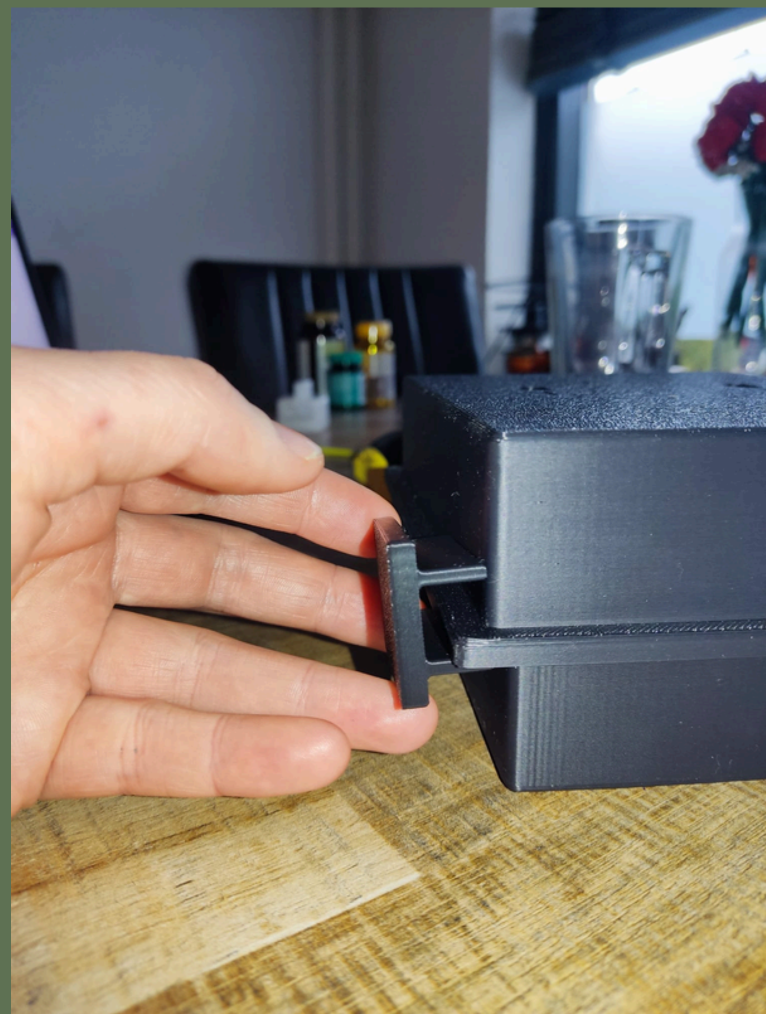

lampen bovenop in de deksel
kan ook aan binnenkant
groeilampen in ventilatierooster
USB
lampen in elke hoek deksel
HKJ
groeilampen toevoegen aan de kweekbak
LED in PVC buis
lampen aan randen deksel
licht onderkant bak
hang de bakken boven elkaar
↳ toch veel licht
buigbare nek


Morphological Chart
Which information?
When water?
How much water?
Which soil?
Sowing depth
How much seeds
Time to sow
Info plant type
Growing stages
How to prick out?
When picking out?
How to sow?
Facts about plants
Soil Moisture
Light intensity
Optimale Temperature
Problem recognition
Growth progress
When to sow new seeds
How to connect something?
Magnets
Hooks
Screws
Clamp
Slot
Glue
Telescopic pole
clicking
Lego
Ropes
Tape
How much information?
Only when needed
Minimal
Easy messages
water
light
Limited
Support
Average
LEARN
Every step
Elaborated info
User can choose
Cleaning design
Diswasher
Loose parts
Soft
Lumpy
Smooth material
Water resistant
Cleaning agent
No small edges
Watertight sensors
Convey information
App
Display
Card (game)
Book
Qr-code
Sounds
Light/colors
Labels
Augmented reality
Digital manual
Messages
Icons
Black/white
E-ink screen
Progress bar
Buzzer
Mechanic movements
RED
GREEN
Shape change
Touch, information
Gamification
Webdashboard
Wearable integration
Community platform
Ideas windowsill
Staircase
Hanging
Windowsill extension
Modular design
Hexagon stack
Artistic rotating
Modular drawer
Extendable tray
tray tower
Other ideas
On wall
Hanging ceiling
Carrousel
Tv furniture
cupboard with storage
Hydro-tower
Foldable rack
rack on wheels
Table with sowing tray in it
Big rack with trays
Store design
Foldable
Loose parts
Part lay in
Bucket for every part
Sticks retractable
Storage in tray
Accordeon
Tray to P9
Silicon lid foldable
Drawer
Rollable container
Light in lid
Flat as possible
Bucket and design in 1
Connecting with nature
Show realtime grow
Spring
Summer
Autumn
Winter
Connect to seasons
Day-night
Natural shapes
noises nature
Feeling soil
Grow over time
Plantcombination
Watering
How does it grow in nature?
Growing stages
Talking community
Which power source?
None
Adapter/Socket
USB
Powerbank
Chargeable battery
solar-energy
Battery
Magnetic
Hybrid
Energy
Kinetic charge
What to measure
PH value
Ph value
moist
soil moisture
Soil temperature
Water level tank
Drainage sensor
Light-intensity
Light spectra
Humidity
Air temperature
Length plant
90%
Battery level
20:00
20-10-'25
Time/date
Different parts
Loose trays
One big tray
Big tray with different parts
P9 container
Holes in tray for water
Different sizes
Waterreservoir
Lid
Moisture sensor
Information about functioning
Stability
Fold out legs
Big surface area
Stable surface
Strong materials
Additional reinforcement
Screwing
Ropes

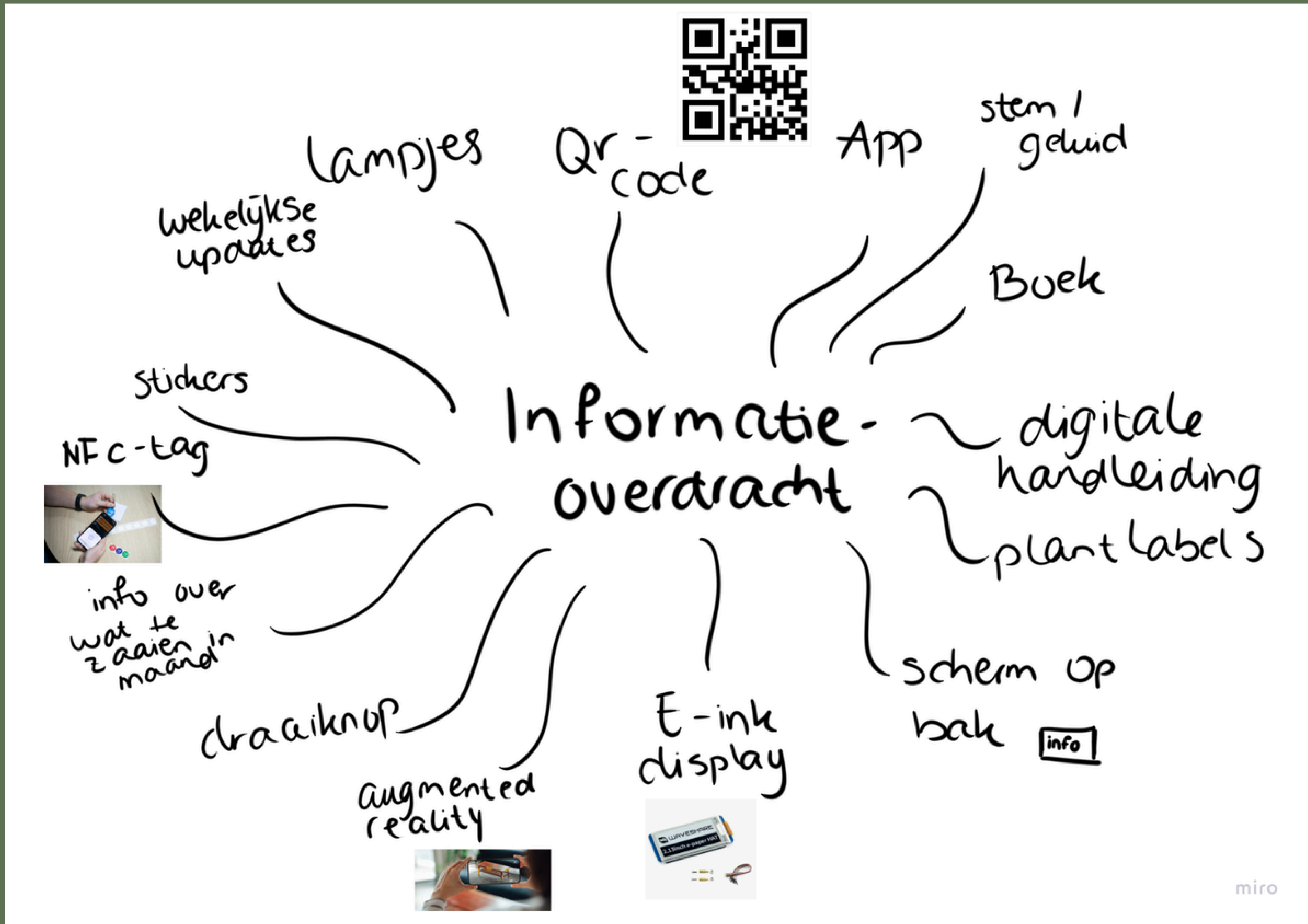
APPENDIX 8: MOISTURE SENSORS

TESTS

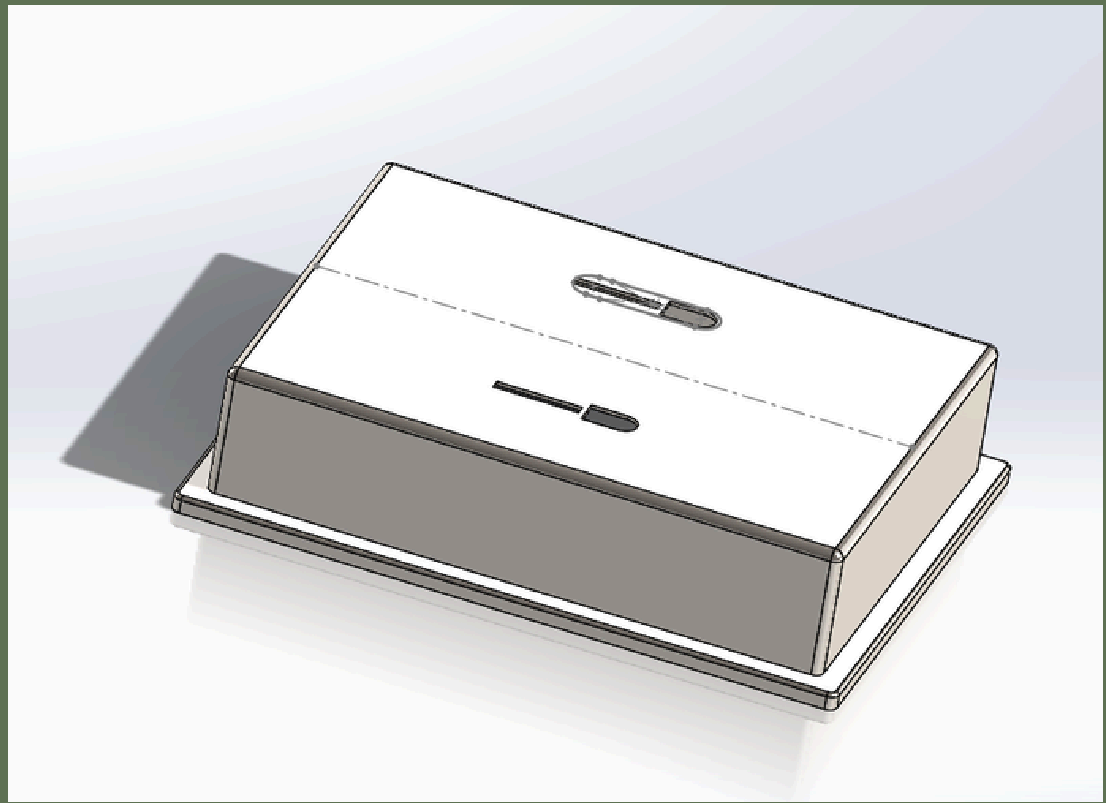




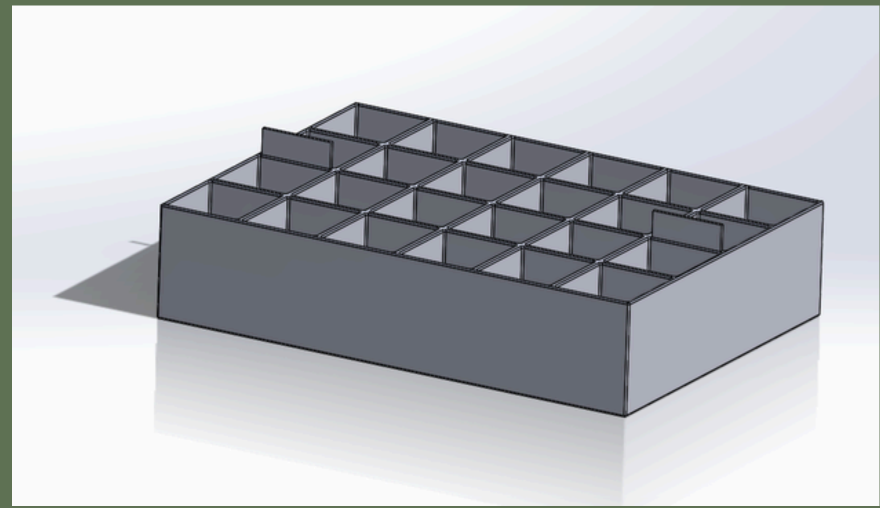
APPENDIX 9: IDEAS TRANSFERRING INFORMATION



APPENDIX 10: SOLIDWORKS MODEL

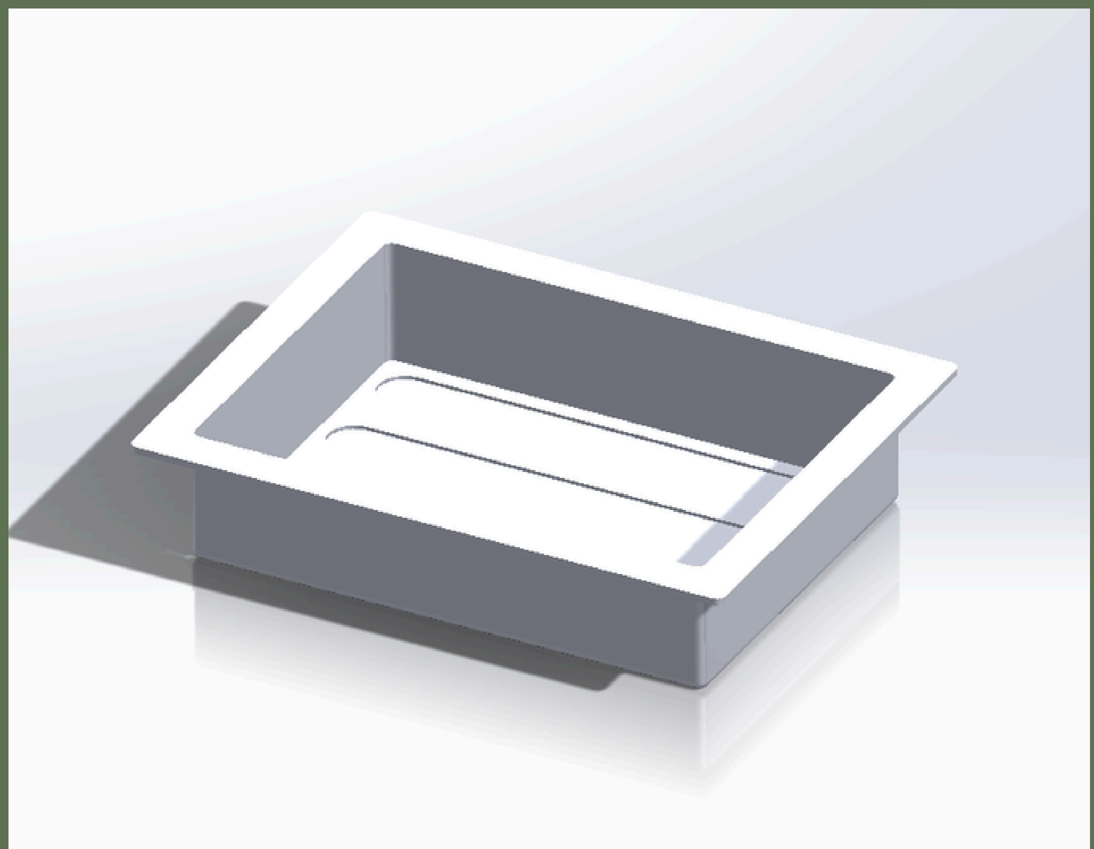


LID

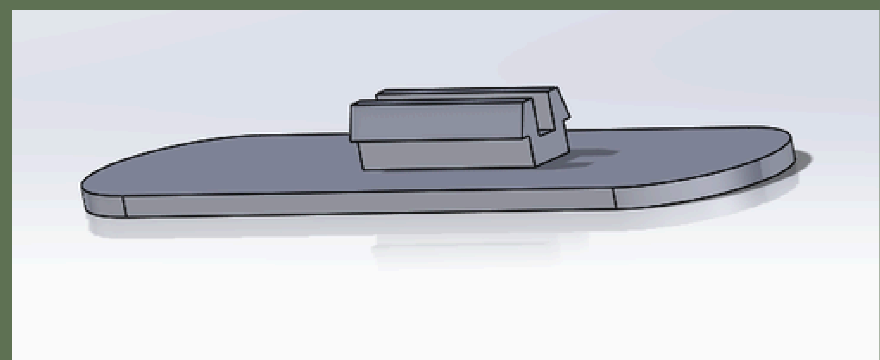


INLAY SIDE VIEW

INLAY TOP VIEW



BOTTOM



VENTILATION SLIDER

APPENDIX 11: SKETCH ARDUINO

```
// ===== PINNEN =====
const int sensorPin = A0;

// LEDs
const int greenLed = 8; // 25–40% → goed
const int yellowLed = 9; // 20–25% → iets te droog
const int orangeLed = 10; // 10–20% → te droog
const int redLed  = 11; // 0–10% → veel te droog

// ===== KALIBRATIE =====
// Pas deze waarden aan op jouw sensor!
int dryValue = 550; // Sensorwaarde bij droge aarde
int wetValue = 200; // Sensorwaarde bij natte aarde

void setup() {
 pinMode(greenLed, OUTPUT);
 pinMode(yellowLed, OUTPUT);
 pinMode(orangeLed, OUTPUT);
 pinMode(redLed, OUTPUT);

 // Test: alle leds kort aan
 digitalWrite(greenLed, HIGH);
 digitalWrite(yellowLed, HIGH);
 digitalWrite(orangeLed, HIGH);
 digitalWrite(redLed, HIGH);
 delay(1000);

 digitalWrite(greenLed, LOW);
 digitalWrite(yellowLed, LOW);
 digitalWrite(orangeLed, LOW);
 digitalWrite(redLed, LOW);

 Serial.begin(9600);
}

void loop() {
 int sensorValue = analogRead(sensorPin);

 // Omrekenen naar VWC (%)
 int vwc = map(sensorValue, dryValue, wetValue, 0, 100);
 vwc = constrain(vwc, 0, 100);

 Serial.print("Sensorwaarde: ");
 Serial.print(sensorValue);
 Serial.print(" VWC: ");
 Serial.print(vwc);
 Serial.println("%");

 // Alle leds uit
 digitalWrite(greenLed, LOW);
 digitalWrite(yellowLed, LOW);
 digitalWrite(orangeLed, LOW);
 digitalWrite(redLed, LOW);

 // ===== LED LOGICA =====
 if (vwc < 10) {            // 0–10%
  digitalWrite(redLed, HIGH);
 }
 else if (vwc < 20) {        // 10–20%
  digitalWrite(orangeLed, HIGH);
 }
 else if (vwc < 27) {        // 20–25%
  digitalWrite(yellowLed, HIGH);
 }
 else if (vwc <= 40) {        // 25–40%
  digitalWrite(greenLed, HIGH);
 }
 else {
  // >35% → te nat / geen waarschuwing
  // alles blijft uit
 }

 delay(1000);
}
```

APPENDIX 12: LCA'S

LCA ALUMINIUM VS STEEL

Manufacturing	Eco-intensity (impacts/kg)	Mass per item (kg)	Items per func.unit (#)	Uncertainty %	Notes	Calculated Impact
Aluminium	7,27	0,422	1,00			3,06703
Recycled aluminium	2,81	0,422	1,00			1,18547
Steel	2,31	1,228	1,00			2,83625
Recycled steel	0,53	1,228	1,00			0,65074
Recycled stainless steel	1,78	1,203	1,00			2,14134
						0
End of Life	**Eco-Intensity (impacts/kg)**	**Mass per item (kg)**	**Items per func.unit (#)**	**Uncertainty %**	**Notes**	**Calculated Impact**
Recycling Aluminium	-3,90	0,619	1,00			-2,4131
Recycling steel	-0,23	1,228	1,00			-0,2824
						0

LCA HDPE VS WOOD

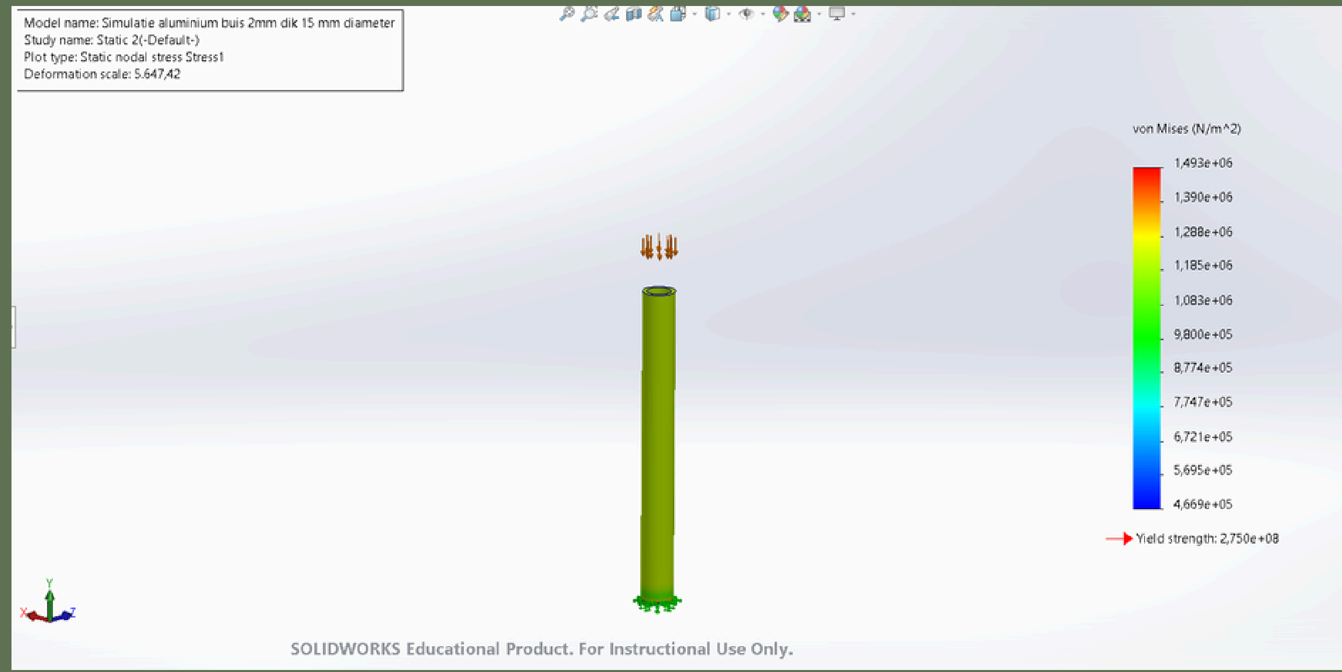
Manufacturing	Eco-intensity (impacts/kg)	Mass per item (kg)	Items per func.unit (#)	Uncertainty %	Notes	Calculated Impact
HDPE	1,80	4,000	0,20	30%		1,44
Beechwood	0,05	3,000	0,25	30%	32 euro	0,0375
Pinewood (Netherlands)	-0,24	2,000	0,50	30%	5 euro	-0,24
Birch	0,15	3,000	0,25	30%	17,7 euro	0,1125
						0
						0
						0

LCA PP VS ABS VS LDPE VS HDPE

Manufacturing	Eco-intensity (impacts/kg)	Mass per item (kg)	Items per func.unit (#)	Uncertainty %	Notes	Calculated Impact
PP	1,63	0,530	1,25	30%	Het gewicht is v	1,08271
ABS	3,10	0,607	0,83	30%	Het gewicht is v	1,56397
HDPE	1,80	0,580	1,75	30%	Het gewicht is v	1,827
LDPE	1,87	0,546	2,50	30%	Het gewicht is v	2,55255
						0
End of Life	**Eco-Intensity (impacts/kg)**	**Mass per item (kg)**	**Items per func.unit (#)**	**Uncertainty %**	**Notes**	**Calculated Impact**
PP	-0,34	0,530	1,25	30%		-0,2253
ABS	-0,02	0,607	0,83	30%		-0,0101
HDPE	-0,02	0,58	1,75	30%		-0,0244
LDPE	-0,024	0,546	2,5	30%		-0,0328

Note that the transport and use are not filled in, in the tables. There is assumed that these are approximately the same with each material

APPENDIX 13: SOLIDWORKS FORCE SIMULATION



The image shows a simulation of a vertically placed component under load, with colors indicating von Mises stress. Stresses range from ~4.7 × 10^5 to 1.49 × 10^6 N/m², well below the material's yield strength of 2.75 × 10^8 N/m². This means the component will not undergo plastic deformation. The calculated safety factor is ~184, indicating the part can easily withstand the load.

APPENDIX 14: CALCULATION PRODUCTION COSTS ITERATION 1

Kostenberekening	
Aluminium: buizen 15mm = 37,49 gram	Metalimex.nl
buiten 8mm diameter= 6,23 gram	
Materiaalkosten aluminium= 1.70/kg = 0,60 euro	
Verwerkingkosten= 6 euro/kg= 1,95 euro	
Poedercoaten= 42,50 per m^2	Coating.nl
Totale m^2 buizen=0,13104208	
Dus poedercoating= 42,5x 0,13104208= 5,57 euro	
Hout:	
Totale lengte nodig: 2472	Praxis.nl
Bij praxis lengte vuren 2700= 4,80 euro	
Zagen per snede= 0,50, 7 snedes nodig dus 3.50 (gratis als je klant bent)	
Totale m^2= 0,1978	
Verwerkingskosten:	
Schaven= 25 euro/m^2-> 4,95 euro	
Beitsen= 10 euro/m^2-> 1,98 euro	Tuinweb.nl
Frezen= 10 euro/m^2 ->1,98 euro	

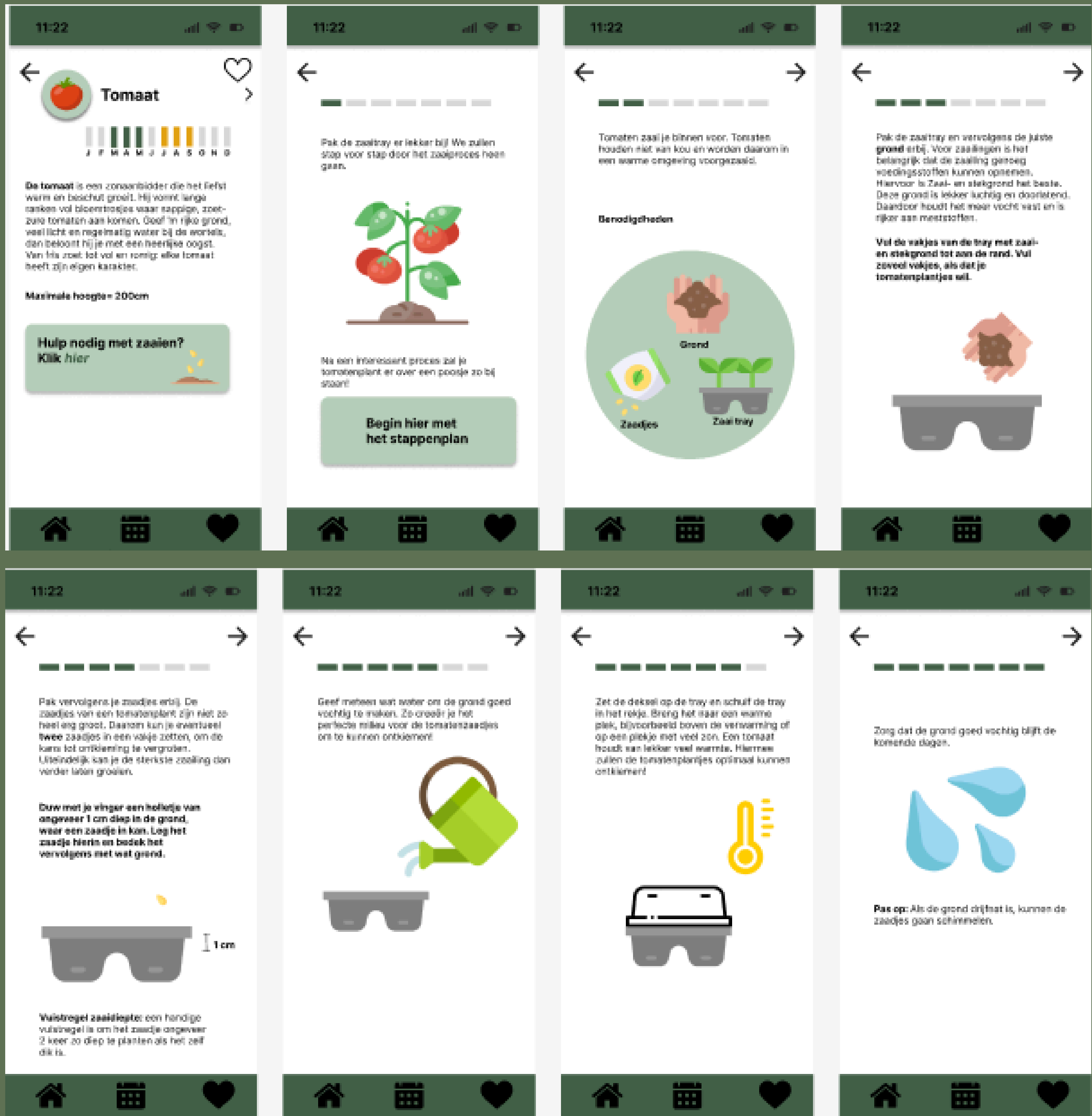
The above image shows the calculations for the production costs of iteration 1. These calculations are based on facts and assumptions. Precise costs do not need to be determined at this stage. The sources consulted are listed in the table.

PP gehele bak rond de 3 euro	
Injection moulding	Rob Thompson Boek
Materiaal= 0,80-1,20 euro (schatting op 1)	
Mal= 2000-5000 euro	
Productiekosten bij 1000 stuks= 1,50-2,00 euro	
Thermoforming (2x)	
Materiaal= 0,50-0,80 euro	
Mal= 200-500 euro	
Productiekosten per stuk (uitgaande van 1000 stuks)= 0,70-1,00 euro	
Led button clips= 0,89 eurox 4= 3,44 euro	rockwestcomposites.c
Electronica:	
Moisture sensor= 1 euro	bol.com
PCB= 0,40 euro	jlcpcb.com
Leds= 0,10 euro	hobbyelektronca.nl
Led strips= 4.50 euro	Grandado.com
Magneten= 0,075 euro	Cuboss.com

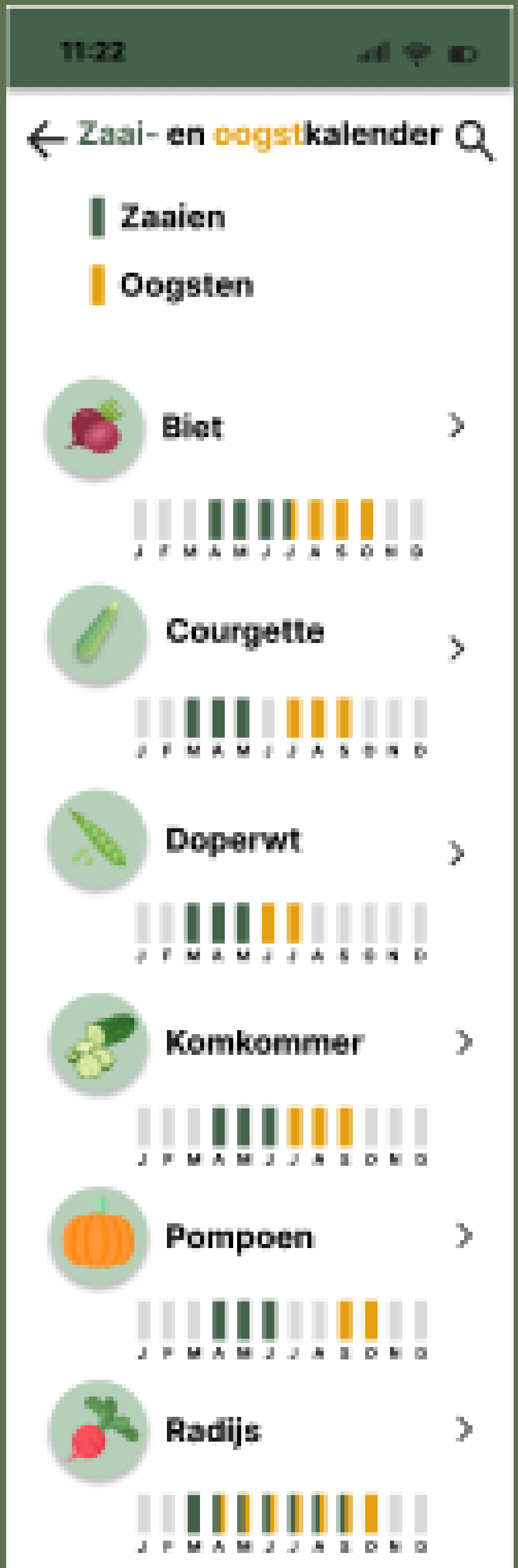
APPENDIX 15: FEATURES APP

When sowing, you will get a whole list of the steps you need to take. In this way, the user knows exactly what to do

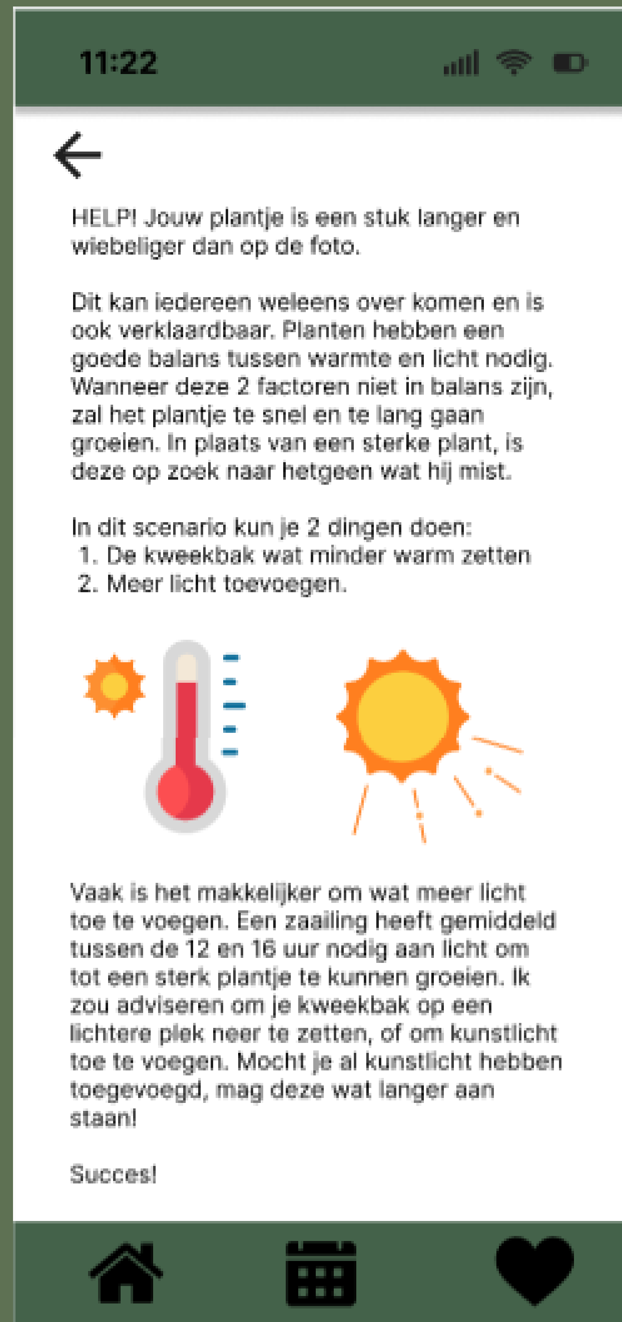
Per month, the user will get an overview of everything that can be done. In this way, the user can try out new things (and learn from this).



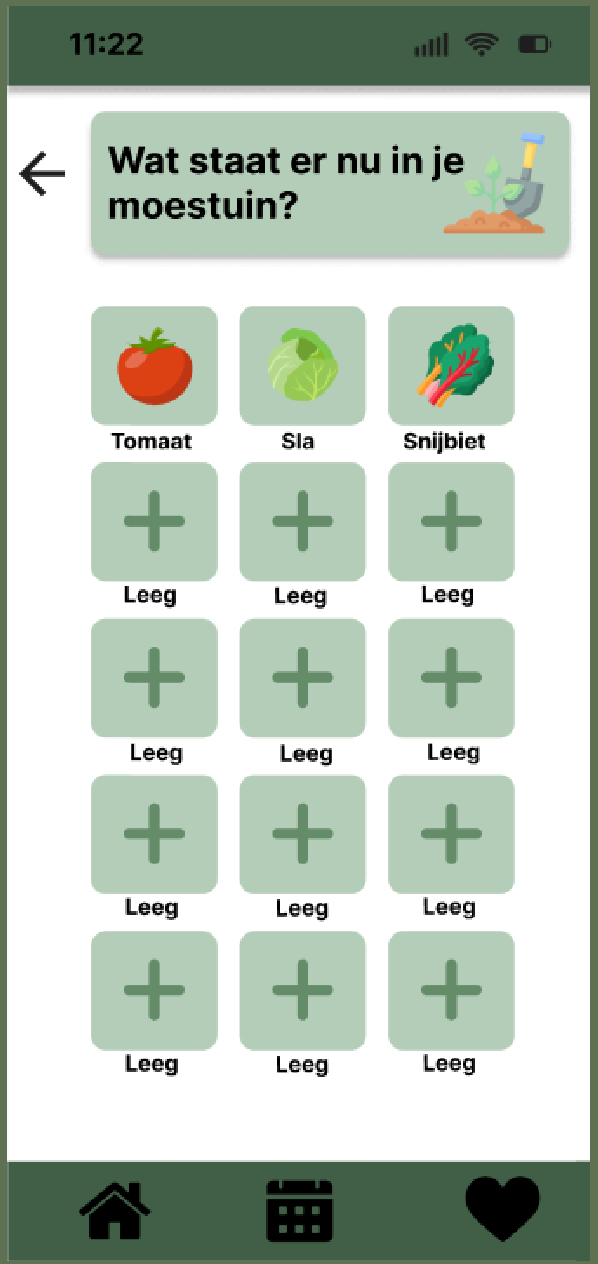
The user will get an overview of everything that you can sow with and when. There is a lot information available per crop, such as the perfect environment and a timelime of growing the crop.

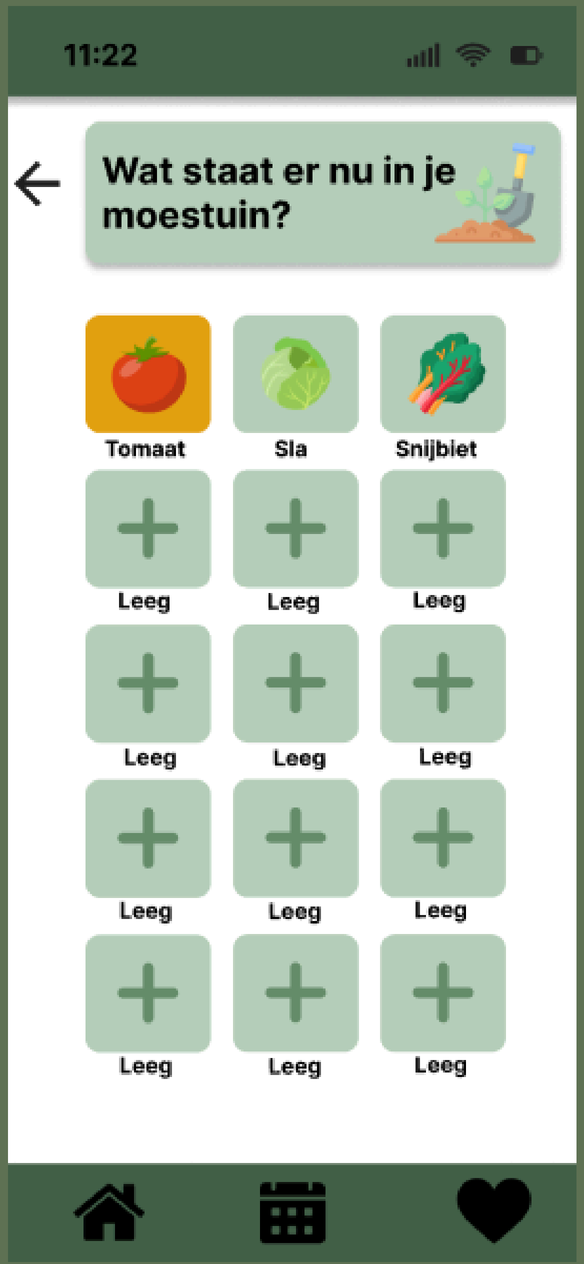


As user, you can get messages to check if everything is allright with your plants. You'll be given a comparison with how your plant should look When something is wrong, you can get feedback from the app. In this way, you can learn from your mistakes (if you made them).



The orange color shows that there is something that you can achieve that day specific per crop. It will be explained what you can do and how.





In the community, you can ask your questions. Other people using the app can answer. In this way, the users can help each other out. There is also the possibility to share something that you are proud of. People can learn from each other and inspire each other.

11:22

Community

In deze community helpen wij elkaar graag en zien we elkaar graag groeien! Je kunt vragen stellen als je het even niet meer weet. Zo kunnen we tips aan elkaar geven en daarbij vragen beantwoorden.
Ook ben je vrij om te laten zien waar je nu mee bezig bent, of waar je enorm trots op bent! Zo kunnen ons enthousiasme delen en elkaar blijven inspireren! ❤

Vragen?

Deel je resultaten

11:22

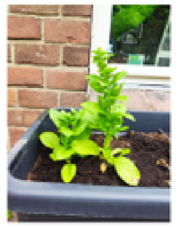
Vragen

Stel hier je vraag:

Anderen vroegen:

Moesmama: Spinazie schiet in het zaad 05-08

Afgelopen maand ben ik begonnen met het kweken van spinazie. Ik werd erg enthousiast van hoe snel het groeide in mijn kasje, maar al snel begon de spinazie in het zaad te schieten.. Ik snap niet zo goed wat ik verkeerd doe, kan iemand mij helpen?



Moestuinmarijke antwoord: 05-08

Spinazie is een gewas wat slecht tegen warmte kan. Ik zou adviseren om wat vroeger of later in het seizoen te zaaien. Ik zou de spinazie lekker in de schaduw zetten, of in ieder geval op een plek uit de directe zon! Veel plezier!

Reageer:.........................

Freek: Courgetteplant 02-08

Mijn courgetteplant groeit en groeit. Ik ben daar super blij mee, alleen hij neemt over heel de breedte enorm veel ruimte in. Is er een manier hoe ik deze volgend jaar beter kan kweken zodat hij minder ruimte in beslag neemt?

Stef antwoord: 02-08

Wauw! Wat een prachtige courgetteplant. Ik heb hier de eerste jaren van het kweken van courgettes ook veel moeite mee gehad. Ik ben er afgelopen jaar achter gekomen dat je courgetteplanten ook verticaal kan laten groeien! Je zet dan een stokje bij het kleine plantje en dan bind je hem elke keer weer op als hij groter wordt. Zo zou je zelfs 2 courgetteplanten kunnen neerzetten in plaats van 1 ;)

Reageer:.........................

Anna: Geen bestuiving 24-07

Hallo lieve moestuinierders, ik heb een vraagje aan jullie: Ik heb een hele mooie courgette plant staan met prachtige bloemen in. Deze bloemen gaan mooi open staan, maar als ik dan een paar dagen later terugkom, is de kleine courgette aan het doodgaan. Hoe kan het dat ik elke keer geen courgettes gegroeid krijg uit mijn bloemen?

Gerda antwoord: 25-07

Hoi Anna, wat een mooie bloemen zeg! Het zou kunnen dat je courgette niet bevrucht wordt. Een courgetteplant heeft een mannetje (stengeltje met een bloem eraan) en een vrouwtje (mini courgette met bloem eraan). Het vrouwtje moet bestoven worden door het mannetje, om tot een grotere courgette te kunnen groeien. Je hebt kans dat deze niet bestoven worden, of dat je zelfs geen mannetjesbloem hebt op het moment. Als je wel een mannenbloem hebt, kan je de courgetteplant eventueel een handje helpen. Dit doe je door met een kwastje het stuifmeel van het mannetje, over te brengen naar het vrouwtje. Zo ben je niet afhankelijk van een hommels/bijen in je tuin.

Reageer:.........................

11:22

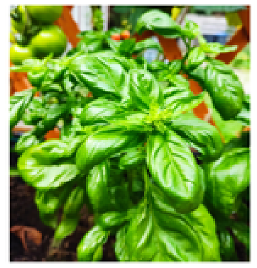
Deel je resultaten

Deel hier je resultaten:

Resultaten van anderen

Moesmama 18-06

Ik ben de afgelopen maanden bezig geweest met het maken van een 'tomatenmuur' met basilicum ervoor. Ben echt zo blij met hoe het er nu bij staat! En die geur die hier vanaf komt is ook zo ongelooflijk lekker :)



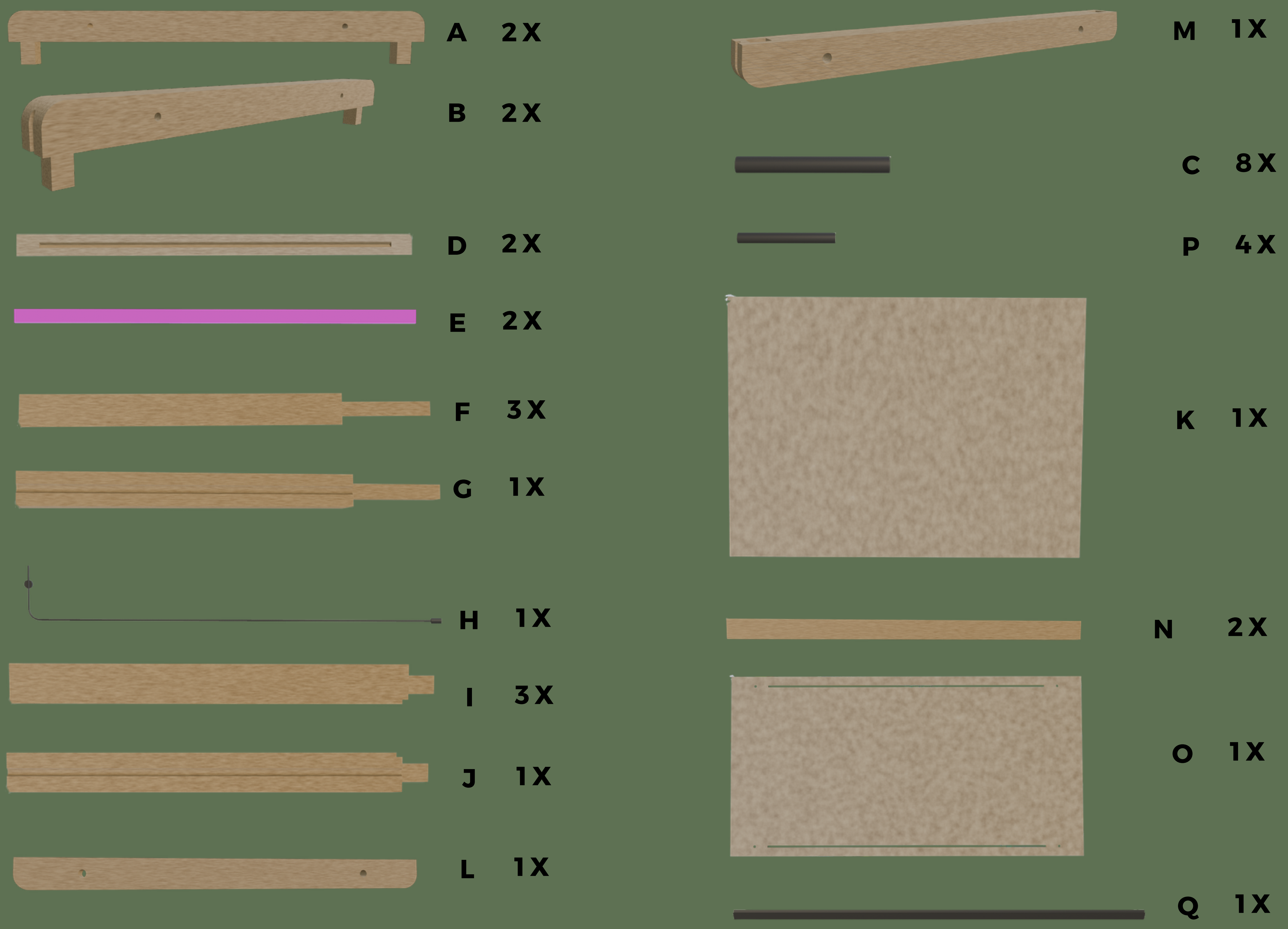
0 4

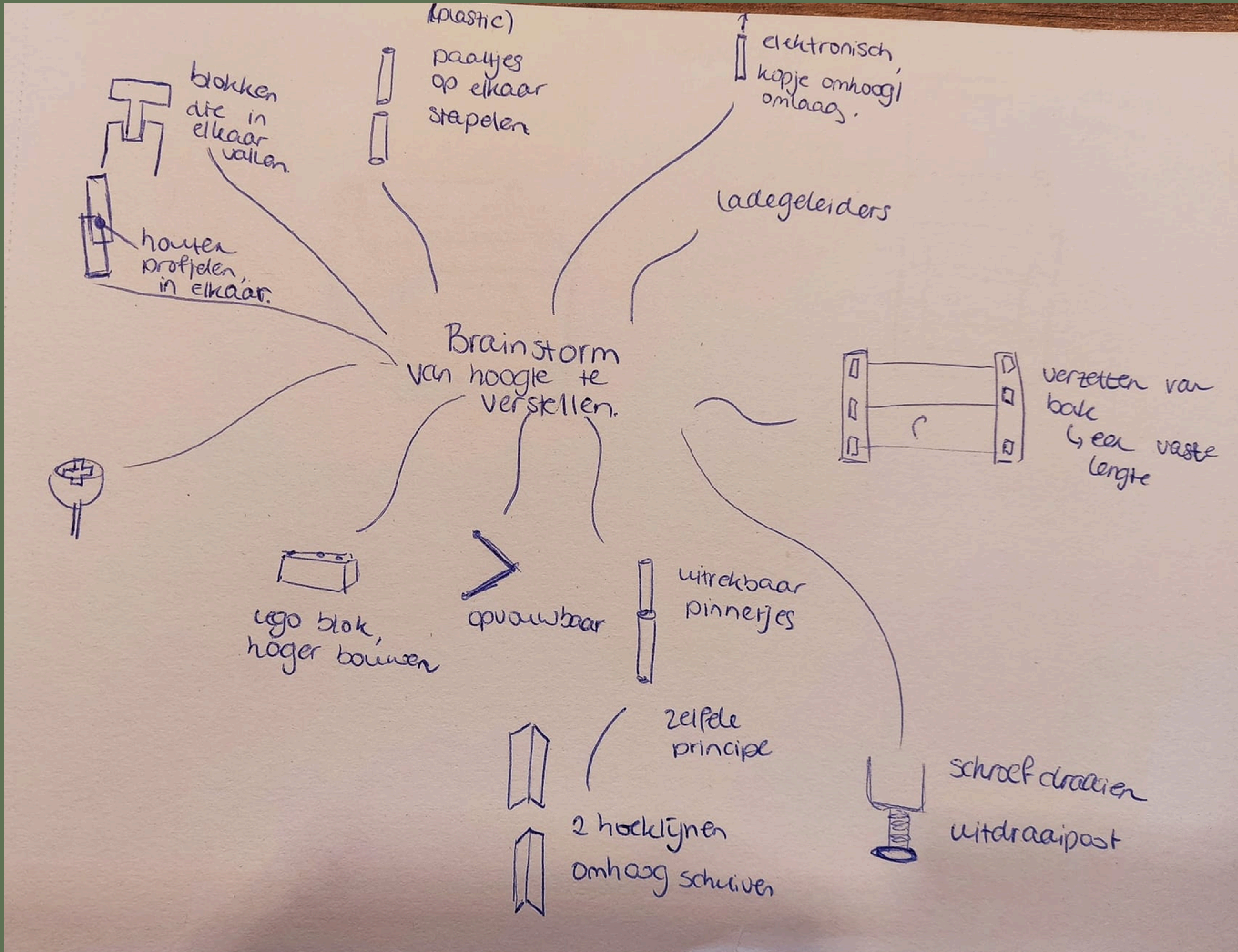
Bloem 08-06

Mijn tomaatjes beginnen rustig aan te rijpen. Vannochtend toen ik in de moestuin liep, kwam ik dit plaatje tegen. Hoe leuk ziet dit eruit! ps, hierna heb ik het rode tomaatje snel opgesmikkeld, zoo lekker!

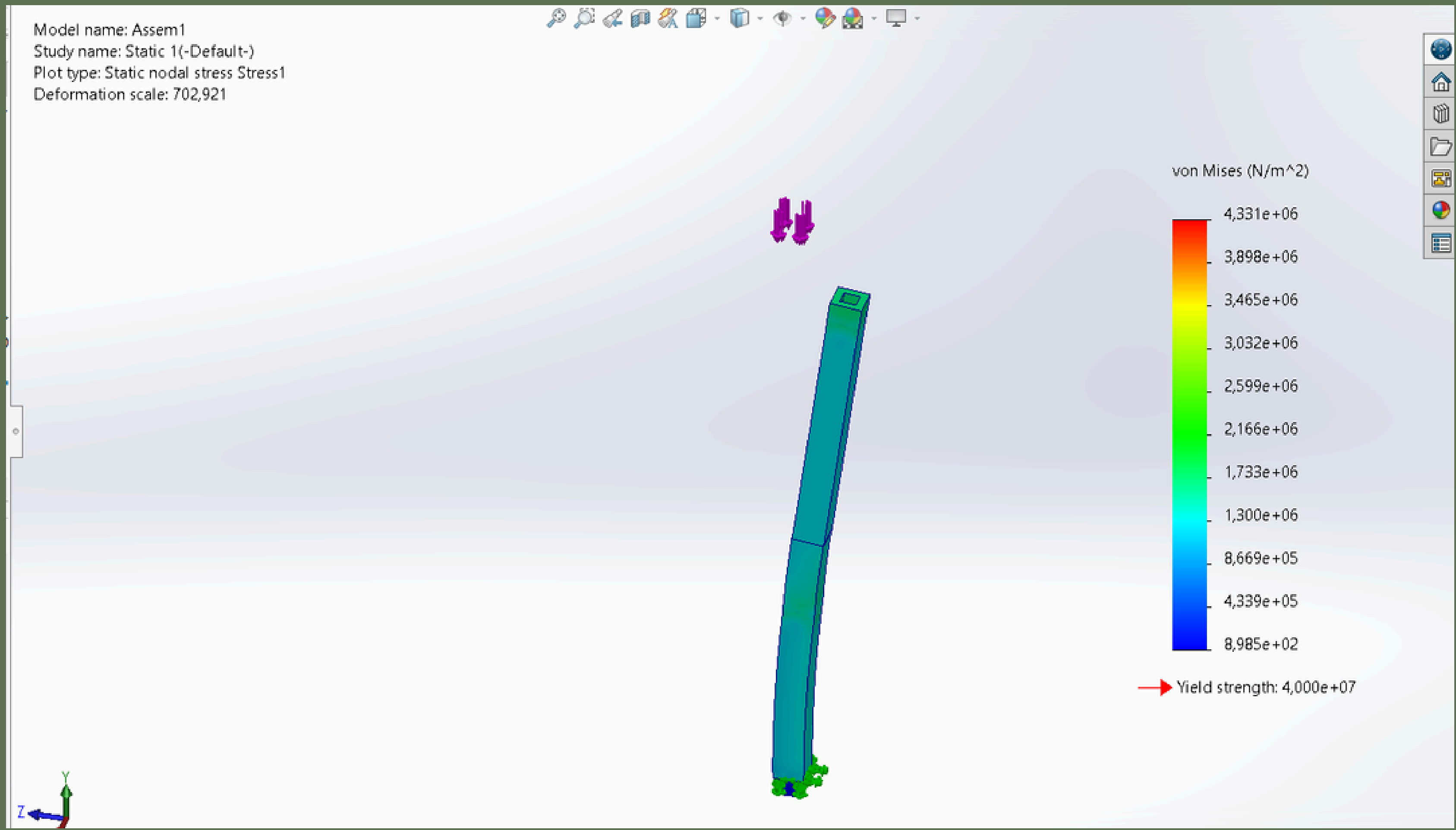
0 12

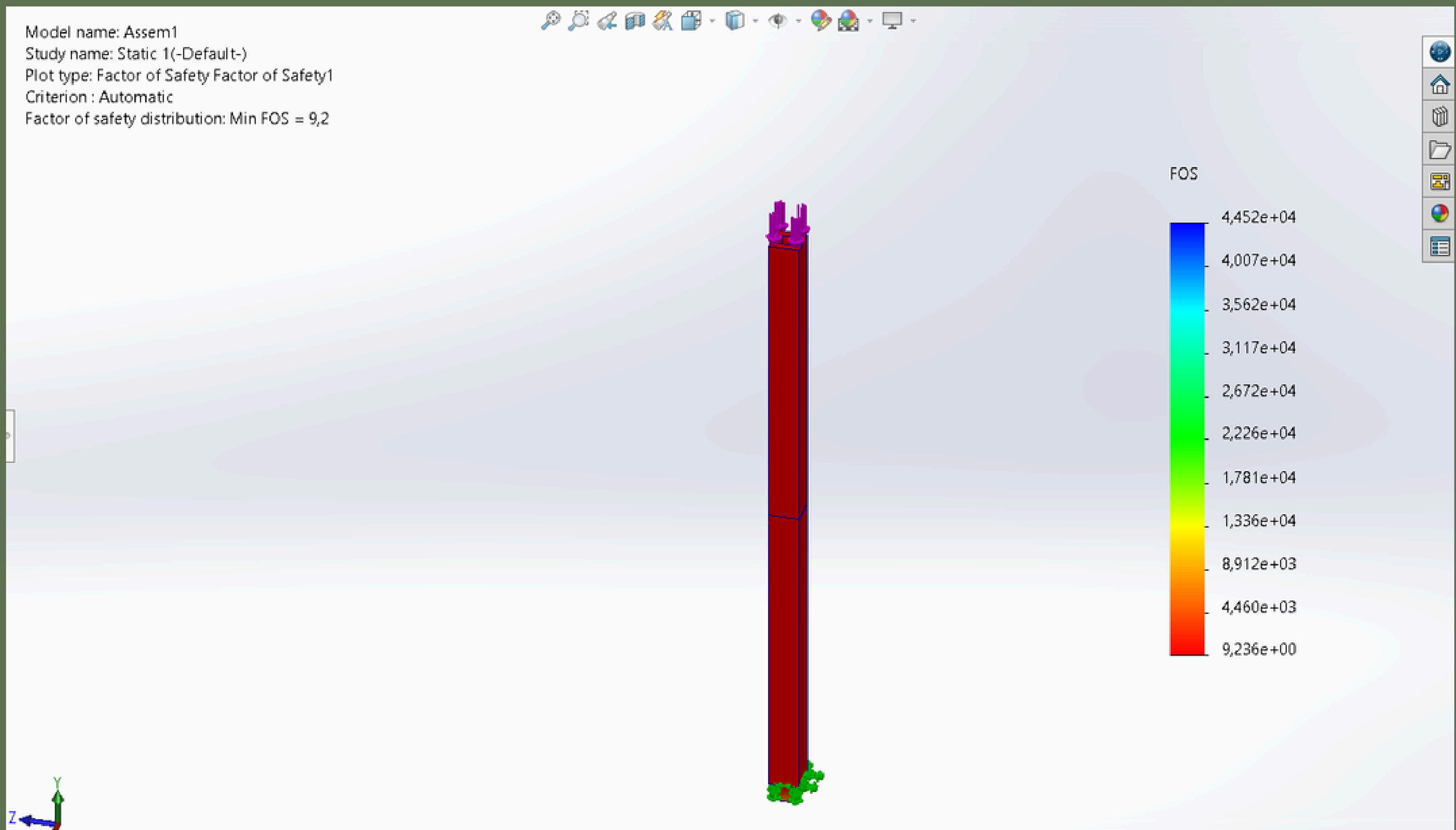
APPENDIX 16: OVERVIEW DIFFERENT COMPONENTS




(plastic)
paaltjes op elkaar stapelen
elektronisch, kopje omhoog/omlaag.
blokken die in elkaar vallen.
houten profielen, in elkaar.
Ladegeleiders
Brainstorm van hoogte te verstellen.
verzetten van bak
↳ een vaste lengte
lego blok, hoger bouwen
opvouwbaar
uitrekbaar pinnetjes
zelfde principe
2 hoeklijnen omhoog schuiven
schroef draaien
uitdraaipoot

APPENDIX 18: SIMULATION SOLIDWORKS





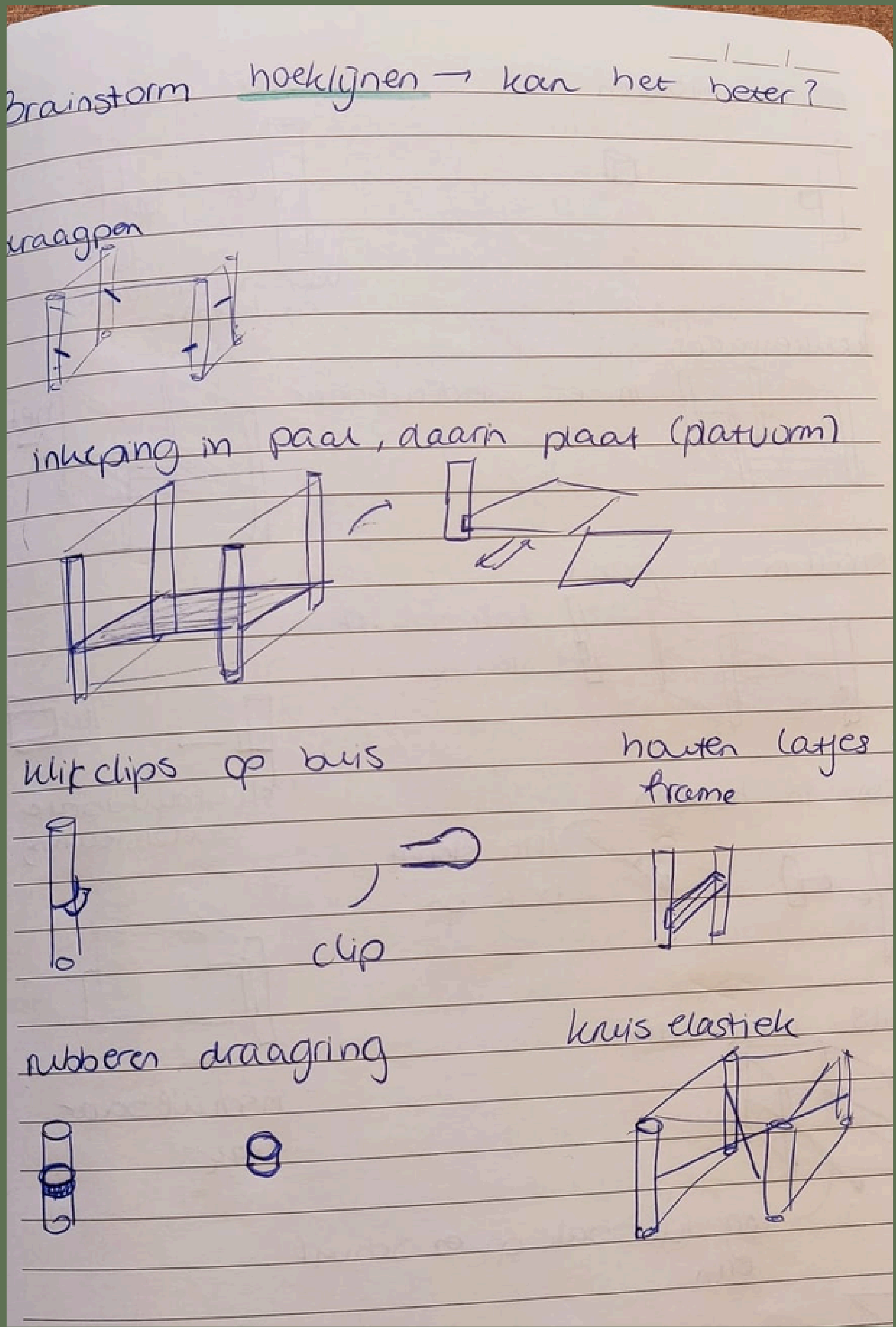
To verify that the wooden supports are sufficiently strong and stiff, a static FEA simulation was performed using a material strength of 40 MPa.

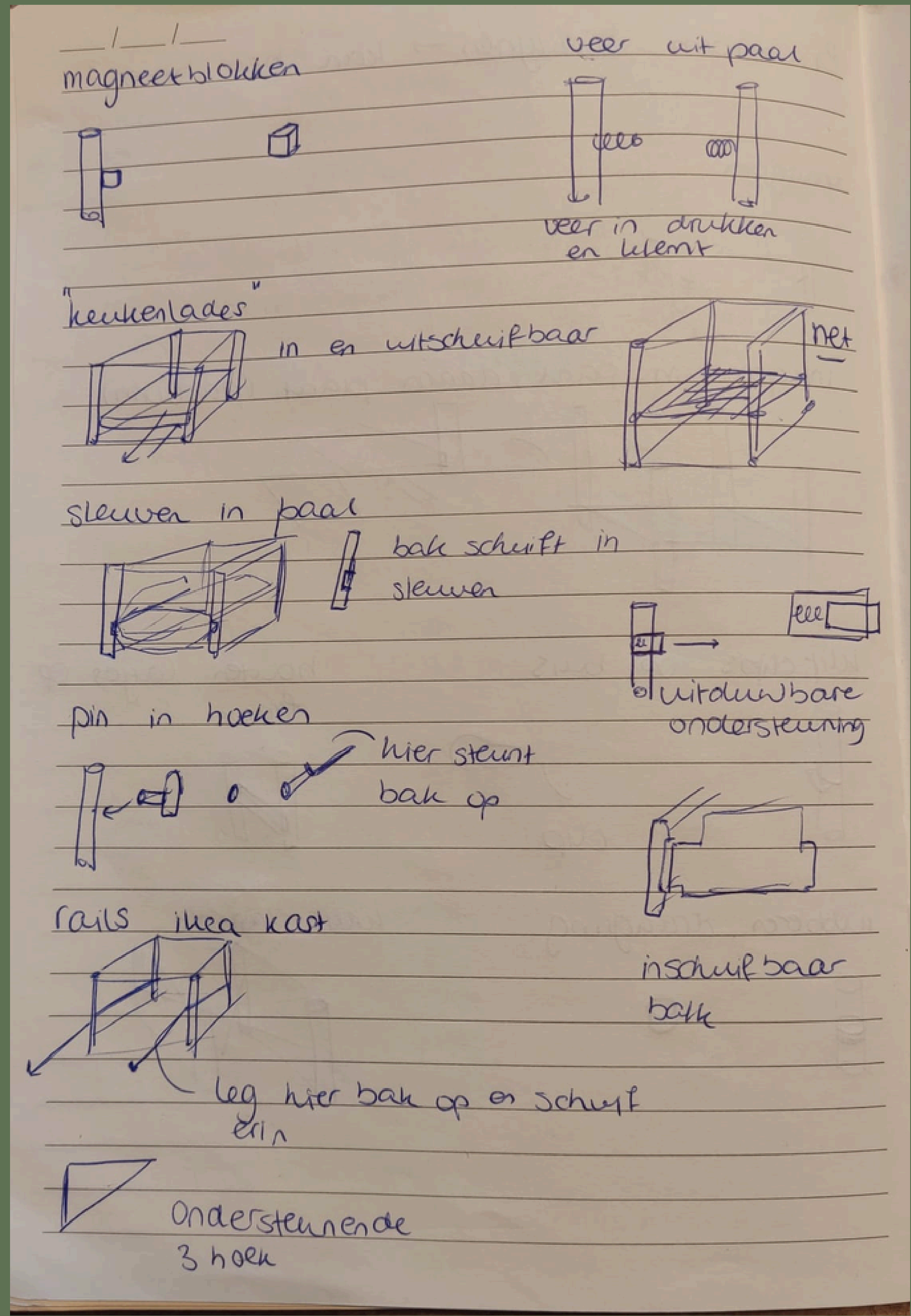
Results:

- Safety: The minimum Factor of Safety (FOS) is 9.2, indicating that the structure can withstand loads much higher than those tested.
- Stresses: Maximum stress is 4.35 MPa, well below the yield strength, with stresses concentrated at the connections.
- Deformation: The displayed deformation is highly exaggerated; in reality, deflection is very limited.

Conclusion:

The wooden supports are more than strong and stiff enough for the growing tray. For practical use, a conservative safe load of 40–50 kg per support is recommended, resulting in a total capacity of 160–200 kg for four supports. The simulation confirms that the structure provides a safe and robust foundation for the modular growing system.





Iteration 1 used metal corner profiles to support the growing tray. Because these were not optimal in terms of attachment and required additional precision, an alternative solution was explored. The images below show several ideas that were considered. From this exploration, the base panel concept was selected, as it is simple and simultaneously creates a storage compartment. This directly supports Requirement 11: Storage.

Frame	
totale lengte nodig hout= 108 cm	
totaal aantal m^2= 0,211759 m^2	
Vuren per 2700mm= €4,80	Praxis.nl
2 lengtes nodig dus= €9,60	
Berken plaat 600x300mm= €3,10	Atmowood.nl
734x455mm nodig= €3,10x2=€6,20	
Verwerkeningskosten frame	
Schaven = €25/m^2= 25x 0,211759=€ 5,29	Tuinweb.nl
Beitsen= €10/m^2=10x 0,211759= €2,12	
Frezen= €10/m^2=10x 0,211759= €2,12	

Kweekbak	
Injection moulding 2x	
Materiaal=€0,80-1,20 (schatting op 1)	
Mal=€ 2000-5000	Rob thompson boek
Productiekosten bij 1000 stuks= €1,50-2,00	
2 keer gemaakt dus totaal = €3-4	
Thermoforming	
Materiaal= €0,50-0,80	
Mal= €200-500	
Productiekosten (uitgaande van 1000 stuks)= €0,70-1,00	
Totale kosten kweekbak= €4,-	

Electronica	
Moisture sensor= €1	bol.com
PCB=€0,40	jlcpcb.com
Led lampjes= €0,02 per stuk= €0,02x4=€0,08	hobbyelektronica.nl
Magneetjes =0,075 x4=€0,3	Cuboss.com
Dc-connector= €0,53	Allekabels.nl
Led strips= €5,67	openelab.io
Led strips connectors= €0,95	ledstripXL
Digitale tijd-schakelaar module= +- €4	elektronicavoorjou.nl
Opbergen tas	
Biologisch katoenen tas= €3,55	Druut.com
Verpakkingsmateriaal verzenden	
Bij aankoop van 1000 stuks= €0,60-1,20=€0,90	dozencentrale.nl
Kosten maken app:	
Webapp / PWA: €500-1000	online digi beheer.nl
Dus voor een schatting van 1000 stuks verkopen is dat tussen de €0,50-1	
Totaal=€ 47,46	

The above image shows the calculations for the production costs of the final design. These calculations are based on facts and assumptions. Precise costs do not need to be determined at this stage. The sources consulted are listed in the table.