Grow Guru

Team Designation

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Contents

Executive Summary

The purpose of the Grow Guru design project is to identify a real-world problem which users experience and provide a solution to alleviate end users. The problem that the team identified is regarding gardeners with busy lives who don't have the time to care for their indoor plants. The team ultimately decided to create a self-watering indoor plant care system: The Grow Guru.

Research is conducted to find the user's top-ranked needs, which are low maintenance, effectiveness, versatility, and durability. These factors were considered when designing the product. The Grow Guru begins as a couple initial design sketches and later evolves into a physical low-level prototype. User feedback, tests, and analysis guides the concept to the updated design which is a more detailed sketch. This is then realized into a high-level physical prototype which becomes the final prototype design. This design consists of components such as the Arduino board, breadboard, wiring, framework to protect sensitive internal components and improve durability, a water pump and water tube for increased effectiveness and low maintenance, a neo-pixel light ring, a humidity sensor, an LCD screen, and a keypad. The Grow Guru contains key features to achieve a successful approach to quick and easy indoor gardening. These features include a self-watering system to water the plant, various watering interval cycle options via the keypad buttons to accommodate a diverse array of plant species, a grow light to aid the growth of the plant, an LCD screen to display the current cycle mode, humidity percentage, and temperature, a large water basin of which a filtration system allows excess water to seep back down into to be reused for the next cycle (decreasing the refill rate of the basin), and a sturdy, sleek frame to add to the aesthetic quality of the design.

Various tests are involved in the verification and validation process of the product to ensure that the aforementioned qualities are each met. Some of which include a measurement of the water basin capacity, the overall weight of the design with all elements put together, functioning modes, display monitoring, and maintenance time measured in minutes. Market size and comparison of similar products are also considered to gauge the potential success of the design.

As with any emerging product, the Grow Guru is projected to have an economic and social impact. Economically, it is expected to positively impact the market by fostering job creation and stimulating increased consumer spending. Similarly, the Grow Guru is expected to have a beneficial social impact by making the product accessible to a broader spectrum of users across various income levels. This inclusivity enhances the product's potential to serve diverse communities effectively.

In conclusion, the Grow Guru significantly enhances indoor gardening by addressing the needs of busy gardeners with an innovative, low-maintenance design. From initial sketches to a sophisticated high-level prototype, the product's development process ensures it surpasses market expectations. Economically, it fosters job creation and boosts consumer spending, while socially, its affordability and functionality broaden access across broad income levels. The success of the Grow Guru stems from its practical combination of user-focused design and advanced functionality, making it a valuable tool for efficient indoor plant care.

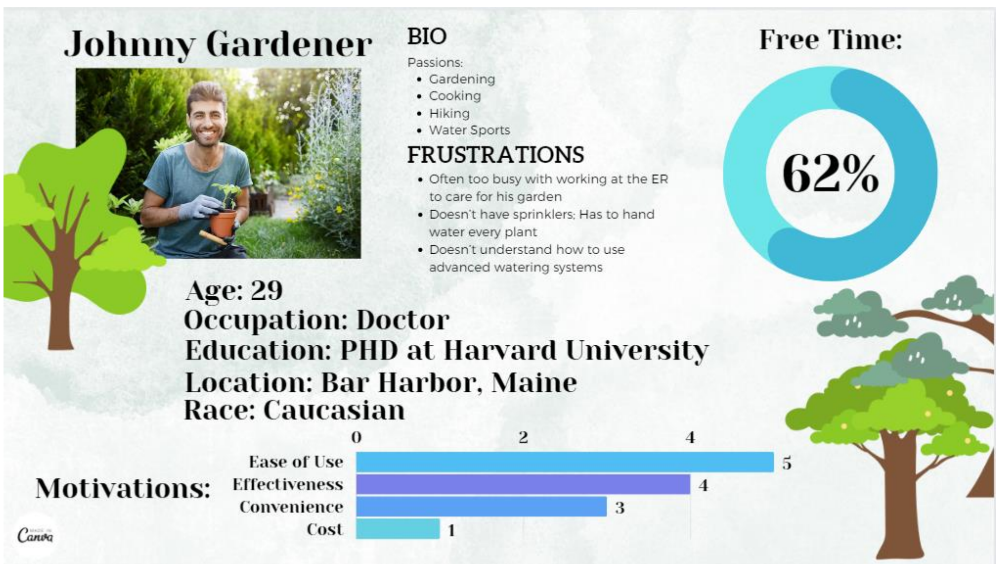
Problem Definition Review

1. Introduction

In today's fast-paced environment, balancing professional responsibilities with personal hobbies like gardening presents a significant challenge for many. Research has identified a broad user group of busy individuals who struggle to find time for gardening due to their demanding schedules and limited familiarity with technology, particularly automated watering systems. This document proposes a solution aimed at this user group, focusing on the development of a product that is efficient, easy to use, and durable. By automating the watering process, the product is designed to alleviate the time constraints faced by gardeners, allowing them to pursue their hobby more freely and with greater satisfaction. The goal is to enhance the gardening experience through innovation, making it more accessible and enjoyable for busy individuals.

2. Problem Definition

User Persona



The interview (B.1) revealed that the user, Johnny Gardener, is a 29-year-old Caucasian male. Gardener got his PHD from Harvard University and now works as a doctor at a hospital in Maine. He is passionate about the outdoors and loves hiking, participating in water sports, and gardening in his free time. He also enjoys cooking his own meals at home.

However, Gardener expressed frustrations regarding his busy schedule. As a doctor who works around the clock, he rarely ever has the time to engage with his passions. He struggles with technology and does not understand how to properly use advanced watering systems for his garden and therefore must hand water each plant. Because of this, it is difficult to manage the garden and his other passions. The graphics (shown in B.2) represent his free time in a circular bar graph, the light blue representing his free-time and the dark blue representing his busy time. His motivations for buying potential products to solve these issues are shown in the bottom bar graph, including the importance of convenience and price for example.

i. User Group Selection

The user group selection is based on the team interviews conducted in P01. The team found that most of the interviewees often had remarkably busy lifestyles and had little to no time to complete their desired hobbies. As it would be unrealistic to target everyone with busy lifestyles and different hobbies, it was decided to focus solely on the hobby encountered by the central user interviewed. Therefore, the user group chosen is busy gardeners. With regards to this, the product developed should be quick, easy to use, effective, and long-lasting so that busy gardeners are relieved of taking the time out of their busy days to maintain the systems.

a. Pains and Tasks

Tasks

- Keeping plants watered and healthy.
- Fitting taking care of plants into a busy schedule.

Pains

- Users with busy schedules can find it difficult to consistently find time to take care of their plants. This means that a hobby such as gardening can go from enjoyable to stressful.
- It can be easy to forget altogether to take care of plants when it is not a main concern for someone. Many users like to keep plants casually or for decor purposes in their homes. For this reason, watering plants is a burden to those who do not find keeping plants enjoyable.
- When someone does not have an automatic sprinkler system, it becomes time consuming to water plants individually. Indoor plants usually do not have an automatic sprinkler system, which results in a higher likelihood that they are forgotten about and not watered.
- It is more difficult to care for plants that require more specific amounts of water which is hard to regulate. Users find it difficult to keep these different plant needs in order, and it is thus troublesome.
- During seasons with less sunlight and lower temperatures, plants that are not regional to the user's location can wilt and die. Many gardeners may want to have more exotic plants; however, their location's climate may not be conducive to keeping these plants healthy.

3. Research Plan

The goal of conducting research is to get a sense of who the user group is and what they want. This will be a very important step in designing the product because it is essential to consider customers first when picking which design qualities to prioritize. The plan for research is to find quality reviews and opinions from real customers. Good sources to find these reviews may include amazon reviews and reddit posts. The main information that is aimed to be collected will be about problems that exist in current products and certain qualities that customers are looking for. In order to keep the research ethical, only reviews and personal information that is already available to the public on the internet will be utilized.

Research Question	Qualitative Data Collection	Quantitative Data Collection
(RQ1) How can the time needed to take care of plants be reduced?	Online blog describing how to take care of plants during vacation [1]	
(RQ2) What factors must be considered to properly take care of a plant?	Gardening website which outlines plant needs [2]	Quantitative study done on plant growth in different environments [3]
(RQ3) How do the needs of different plant types differ or affect the plan for the product?	Blog describing how different plants need different types of care and resources [4]	Study on the growth of different types of plants [3]
(RQ4) What products are currently on the market and how will the proposed design be better?	Specific product review [5] Gardening blog list of current products and reviews [6]	Amazon page listing current products [7]
(RQ5) What characteristics would users be looking for in a product like this?	Reddit post listing the specifications that a user is looking for in a product similar to the proposed product design [8] Individual user looking for a plant watering system [9]	

4. Research Results

a. Creating User Value

Gains

- Busy gardeners can enjoy more free time not dedicated to responsibilities. The relief of another responsibility, no matter how small, means a lot when someone has a busy schedule. This can also greatly improve someone's stress levels as hobbies and free time are essential to living a healthy and happy life. According to Dina Smith, "research has shown they're [hobbies] good for your physical and mental health, can make you more competitive in the workplace, help stave off burnout, and keep your mind sharp through learning new and varied skills." [10] Smith adds that engaging with hobbies can also help build new social bonds with others sharing the same passions and add a richness to your life and identity. This is verified by Venkat S.R. who provides the following example: "A study that measured both positive and negative psychological stress found that those who took time frequently to do leisure activities that they enjoyed had lower blood pressure, waist circumference, and BMI." [11]

- Users that keep plants for decorative reasons but do not enjoy taking care of plants no longer need to worry about remembering to water their plants. Because some users solely keep plants for their aesthetic, having to take care of their plants can become a burden. This burden is removed by the addition of an automatic watering system. According to Luke Revitsky, "When asked about their motivation to own a plant, the top three reasons were to improve air quality, to have something pretty to look at, or to improve the design of their home." [12] This shows that the significant reason people tend to own houseplants is for their aesthetics, although many times they are unsure of how to care for them. The graph provided (B.7) reveals that a whopping 21% of people own plants in order to improve the look of their homes and to have something aesthetic to look at compared to the 12% who wish to actually care for the plants.
- Users who have plants that are difficult to take care of no longer need to keep track of each plant's individual needs. Instead of remembering the individual needs of plants, users can alter watering levels and schedules to each plant. According to Aaron Steil of Iowa State University, it can be easy to over or underwater plants because, "watering frequency changes depending on factors like light levels, temperature, humidity, type of soil and container, plant size, species, and time of year." [13] Instead, ISU suggests *checking* the water levels in a plant's soil. This is exactly what the automated watering system is designed for.
- Users can enjoy healthier and more diverse plants without the effort that it takes to care for them. Having more variety of plants to choose from to decorate a home can add more personality and beauty to a space. This can lead to increased overall happiness of homeowners and plant keepers.

User Needs

- Low Maintenance: The product does not require maintenance by the user after assembly/purchase. On the pairwise comparison chart (See B.3), this user need is ranked as a 5.0 on a scale from one to five. One would rank least important and five would rank most important. This detail determines a key aspect to be considered during the design process of the product. It maps a focus that should be made on ensuring that the final product is easy to maintain and requires little maintenance overall.

- High Quality: The product is made with higher quality production and materials. This user need is ranked as a 3.9 on the pairwise comparison chart. This shows that, when designing the product, *somewhat* high-quality materials should be utilized, and the designers should be careful and critical of the product's overall performance.
- Usability: The product is easy to operate for the user. This user need is ranked as a 3.3 on the pairwise comparison chart. This reveals that the instructions for usage should be easy to understand for the everyday user. One way this could be ensured is to hold a beta testing session with multiple users with little to no engineering background. This study would allow the designers to get a sense of usability of the product and readjust the design in accordance with results.
- Effectiveness: How well does the product do what it is advertised to do? In other words, does the product perform its job? This user need is ranked as a 4.4 on the pairwise comparison chart. Therefore, effectiveness seems to be a very important user need. This shows that the designers must ensure that the final product performs the initial task that it was meant to. This can involve a series of tests of the product in multiple environments, temperatures, diverse plant types, and altering light levels. Making sure the product is not defective and works properly is essential.
- Easy Assembly: Is the product easy to put together/assemble after the user purchases it? This user need is ranked as a 1.0 on the pairwise comparison chart. Easy assembly was found to be one of the least important aspects of the product. When considering this, it was found that after the product is assembled once, it will not need assembling ever again which would make it less important compared to things like the effectiveness and usability.
- Versatility with Plants: Is the product able to meet the needs of different species of plants? This user need is ranked as a 3.9 on the pairwise comparison chart which indicates that it is a crucial factor of the product's design. In order to achieve this, it is necessary to conduct a series of tests with different types of plants over a couple of months. It might be better to use plants of extreme opposite watering and light needs such as Begonias which thrive in lots of water and Cacti which are known to need very little water. This would measure how well the product performs under different plant conditions.
- Aesthetics: Is the product visually appealing to the user? This user need is ranked as a 2.1 on the pairwise comparison chart. Therefore, things like how beautiful it looks in a space or how bulky the product appears are somewhat important but not a key concern for the design. It managed to rank higher than easy assembly because a bulky or ugly appearance of the product can take away from its assets for the users who would want to keep plants for decor purposes.
- Durability: Can the product be used for an extended period of time or will the product break easily? This user need is ranked as a 4.4 on the pairwise comparison chart. Therefore, durability is considered among the significant aspects of the product design. It is important to ensure that the product can be used for a long time and does not break or prove dysfunctional, especially for those with little time or money to go out and buy replacements for it.

i. Pairwise Comparison Chart

	Affordable	High Quality	Low Maintenance	Usability	Effectiveness	Easy Assembly	Versatility w/ plant types	Aesthetics	Durability	Sustainability	Total	Normalized	Predicted
Affordable		0	0	0	0	0	0	0	0	0	0	-	1.9
High Quality	1		0	1	0	1	0	1	1	1	6	3.9	3.7
Low Maintenance	1	1		1	1	1	1	1	0	1	8	5.0	4.5
Usability	1	0	0		1	1	0	1	0	1	5	3.3	3.85
Effectiveness	1	1	0	0		1	1	1	1	1	7	4.4	3.6
Easy Assembly	1	0	0	0	0		0	0	0	0	1	1.0	2.1
Versatility w/ Plant	1	1	0	1	0	1		1	0	1	6	3.9	1.8
Aesthetics	1	0	0	0	0	1	0		0	1	3	2.1	1.5
Durability	1	0	1	1	0	1	1	1		1	7	4.4	3.4
Sustainability	1	0	0	0	0	1	0	0	0		2	1.6	0.5

Using the data from the pairwise comparison chart (See B.3), a better understanding can be gained as to which user needs are crucial for successful systems or products [14]. This chart highlighted which user needs to prioritize over the others through a comparison-based design. After completing the pairwise comparison chart, it was evident that some of the team predictions were spot on while others were not. It was found that the users' most important needs were low maintenance, durability, and effectiveness. Being low maintenance was the most important value, scoring a 5.0 on the normalized scale and as predicted, ranked the highest out of all user needs.

In contrast, versatility scored higher than anticipated with a normalized score of 3.9 compared to the predicted score of 1.8. The user needs that proved to be not as important were affordability with a final total score of 0, ease of assembly with a normalized score of 1.0, sustainability with a normalized score of 1.6, and aesthetics with a score of 2.1. The team believes these user needs were considered less important because the target audience includes individuals with a time-demanding occupation and little free time. A user like this would be most concerned with anything that would save them as much time as possible. An effective, durable, and low maintenance product would work well and long enough that it wouldn't require much time or attention which fits exactly what the user would need.

During the design process, there should be an emphasis on these functional aspects while keeping quality and usability in check, despite these factors not holding the top positions in the pairwise comparison chart. Both quality and usability are directly related to durability and effectiveness because using high quality materials and putting them together well would achieve that high tolerance. Usability would be important too because if a user must waste time trying to figure out how to operate the device, they will ultimately end up frustrated. The user would likely give up and find themselves with no more free time than before because the product is not in use and can't be given a chance to be effective. A crucial factor to keep in mind is having relevant data and integrating user feedback into the user needs, so they are dynamic and not fixed [15].

a. Market Character

i. Stakeholders

Aside from the users, the distributors, investors, communities, and even those in charge of repairing or maintaining the product would also be affected by the potential solution proposed by the team.

Investors would be interested in the market value of the product and would be affected by how well it performs financially. Depending on if the product performs well or not in this regard, the investors could be impacted positively or negatively. Additionally, investors would be directly impacted by users' interest in the product. Investors would be positively affected by an influx in user approval of the product and would likewise be negatively affected by a lack of user interest in the product.

Distributors would also be impacted by the product as they would be the ones involved in selling it. Therefore, they may be interested in ethical questions regarding the product, how well it would perform in the market, and if people would be willing to buy it. If the product is unethical, the community of consumers might communicate issues with the distributors first and even stop buying from them which would negatively impact them. Better ethical practices, such as ethical manufacturing of the product, directly result in more trust and loyalty from consumers, which is the largest factor affecting distributors.

Communities are also stakeholders of the product. Users who choose to utilize the product for outdoor plants will be providing their neighborhoods/communities with a more aesthetically pleasing environment. This would boost community morale and is likely to increase demand as the product is observed by members of these communities.

As for repairpersons, they would be positively impacted because they would get more jobs to fix and maintain the systems.

ii. Market Size

It is predicted that the potential market size will be quite large considering it is a billion-dollar industry. However, because of this, there will also be much competition involved. According to Emerging Research, "the global smart indoor garden market size was USD 110.2 Million in 2020" [16]. This suggests that the proposed product would fare well in the market and would be a product many gardeners would consider buying. In the United States alone, about 15% of 18- to 29-year-olds participate in gardening activities, 23% of 30- to 49-year-olds garden, and 33% of 50- to 64-year-olds also participate in gardening as of 2023 (See B.6 for data graph) [17].

It was found that the key factors driving consumers to buy automated home watering systems such as the presumed product, included a rise in demand for watering systems that do not take up much space as well as the aesthetic component. The Internet may have also played a key role in determining this rise in demand. Online news source, *Socialnomics,* suggests that "platforms like Facebook allow retailers to market *directly* to their target customer demographics [18]." This ability opens the door for users interested in gardening to be influenced by ads, increasing the likelihood that these consumers will become buyers of the product.

The article also mentions that currently there have been trends associated with this rising demand. Specifically, the further technological advancements made towards easing the care of gardens, especially indoor gardens, the more people demand these systems and products. The

Business Research company has found that “rising water consumption is expected to propel the growth of the water supply and irrigation systems market going forward” [19]. This was further demonstrated by a chart provided by Polaris Market Research Analysis [20]. The chart (B.5) shows an increase in market size for smart indoor gardening systems by region from 2018 and prospects for up to 2030. From 2018 to 2019, there began an increase which suddenly drops in the year 2020 which is suspected to be due to the Covid-19 Pandemic and its effects on the global market, individual spending, and going out to stores to buy the systems due to quarantining at the time. But after that it becomes a steady increase all the way up to today and is predicted to remain that way up to the year 2030. Differences between regions are suspected to form based on household income and differing user needs in less privileged regions of the world.

iii. Current Alternatives

User Need	Automatic Drip Irrigation System	Self-Watering Stakes	Rain point Automatic Watering System	LetPot System 2.0	Gardyn Home Kit 3.0
Low maintenance	Pass	Pass	Pass	Pass	Pass
Effective	Pass	Fail	Pass	Pass	Pass
Durable	Fail	Fail	Fail	Pass	Pass
High Quality	Fail	Fail	Fail	Pass	Pass
Versatile	Fail	Fail	Fail	Fail	Fail
Affordable	Pass	Pass	Fail	Fail	Fail
Aesthetic	Fail	Fail	Fail	Pass	Pass

The market for automatic plant watering systems is a large and heavily populated one. Many of the products on the market today are targeted to different user groups, plant types, and people with different needs. From the products that were cross evaluated (B.4) it was noticed that there were some user needs which the alternatives did a good job at addressing, but also a lot that needed improvement.

Mostly all the alternatives passed for being low maintenance and effective, with the outlier of the terra cotta watering stakes [21]. This is predicted to be the case due to the low durability and often replacement that is needed with the stakes. Gaps began to appear and become noticeable when alternatives were evaluated for their durability, quality, versatility, and affordability.

None of the alternatives passed for quality except for the LetPot Automatic Drip Irrigation Kit [5] and the Gardyn Home Kit [22]. However, the opposite trend occurred when looking at affordability. The moistenland Automatic Drip Irrigation Kit [7] and the terra cotta watering stakes [21] passed with good scores for affordability, coming in at less than $60, but failed many other user needs consequently. Lastly, none of the alternatives had good versatility. Currently, it seems that there is no product on the market which offers a simple solution for plant owners who have many different species of plants.

From examining the current alternatives on the market, it is clear that there is a big opportunity for a product to take advantage of the shortcomings which currently exist. It seems it is hard to find a product with a good compromise for all user needs. Many products are good at meeting some needs, but then risk sacrificing the others in the process. Also, there is no helpful solution for a product which can be versatile with different plant types and needs. These gaps are exactly where the Grow Guru will take advantage.

5. Value Proposition

The value in pursuing a product in the automated plant watering market comes from the lack of products that address the user needs of the user group. A specific pain that the user group is looking to solve involves the maintenance associated with taking care of house plants. They are looking for a product that will get the job done right while being low maintenance enough to justify the purchase. If a user is required to spend copious amounts of time either setting up or maintaining a system, it defeats the purpose of an automated system. Additionally, if the product is too cheap and not durable enough, the additional cost involving both time and money of replacing the product every year or two will drive customers away. The Cambridge Dictionary definition of automated is "carried out by machines or computers without needing human control." To market a product as being automated, there should be either zero or minimal human interaction required.

Many of the current products on the market fail to live up to this promise when they market their product as "automated". Reviews for current products suggest many issues because a lot of maintenance and troubleshooting. One example of this involves how one product's "water leaked between the hose and the dripper rather than from the dripper itself. The out-port barbed portion of the pump leaked as well. Because the hose barb is shielded in the pump housing, there is very little that can be done to resolve this issue." [23]. Other customers reported poor durability and product quality. For example, one review states, "When I activate the pump it begins to vibrate like it is running, but then pumps out air into the line toward the plants with an occasional bubble of water. It worked, I was thrilled, it stopped working soon, I am moving on" [23].

This is where the economic opportunity lies. If a product can be created that takes advantage of this market gap and is well advertised, there is a huge amount of value available for it.

6. Design Focus

The overall design focus is to better fulfill potential opportunities in the automated plant watering market that specifically address the unmet needs of busy individuals and plant hobbyists who want a low-maintenance, durable, and automated solution. The research phase aids the team in the understanding of user pains, highlighting common issues that exist with the designs currently on the market and ways to improve upon them. The team's evolution of thinking has evolved throughout the design phase by narrowing down what aspects products should exhibit with consideration of the user's needs. The team saw what specific characteristics went along with each user's need and branched out from them to form the different design characteristics that accompanied the user's need.

One of the key design elements of the product is for it to be low maintenance, involving minimal human intervention with the upkeep and frequency of maintenance of the product. To better ensure the durability of the product, it will incorporate high quality materials and features that ensure long-term product life and avoid the need for frequent replacement of parts or other features. Building the product out of more reliable materials directly contributes to the high-quality factor of the product as well as its longevity. Another one of the top rating factors discovered in the pairwise decision matrix is the need to have versatility with the product. This can be achieved by allowing for various plant sizes and having multiple programs catered toward various plant types. An important factor for the design is for it to be usable without requiring previous knowledge to effectively use the system and allow for success in caring for a multitude of different types of plants.

By prioritizing minimal user intervention, incorporating durable materials for the longevity of the product, and offering versatility for various plant sizes and types through adjustable settings, the product fills a critical gap in the automated plant watering market. By excelling in these three main areas that are important to the users, the team can deliver a high-quality, reliable, and convenient solution.

Concept Development Review

7. Concept Brainstorming and Ideation

a. Process Description

To develop an optimal design for the product, the team needed to look at the key characteristics that were important to the target user group. The important key characteristics are low maintenance, durability, and versatility of the design of the product as they were found to be the top characteristics in the pairwise comparison chart (B.3). To ensure that these characteristics were well incorporated, the design needed to feature high-quality materials, accommodate various plant sizes and types, and be user friendly.

The team's solution for finding the most optimal design was a collaborative approach using the group members' ideas and providing feedback on each other's potential designs. The team started with a 5-minute brainstorming session; the goal was for each of the team members to create a rough sketch of the team members' individual interpretation of the product and certain features that it might have. Then the team members passed their design to the team member next to them with a different color marker to provide feedback on the design and suggestions that may need to be made. The team continued to do this for an additional two times. This was a critical step in the brainstorming process as having multiple interpretations and perspectives on a design will lead to a design that is the most optimal to fulfill the user needs as it is a conglomerate of multiple excellent ideas.

The designs produced by the team featured some similarities but ended up with important feedback and improvements to each one to produce the best design (A.1, A.2, A.3, A.4). The result of this design development process produced several design solutions that consider the target user's top priorities.

b. Brainstorming Results

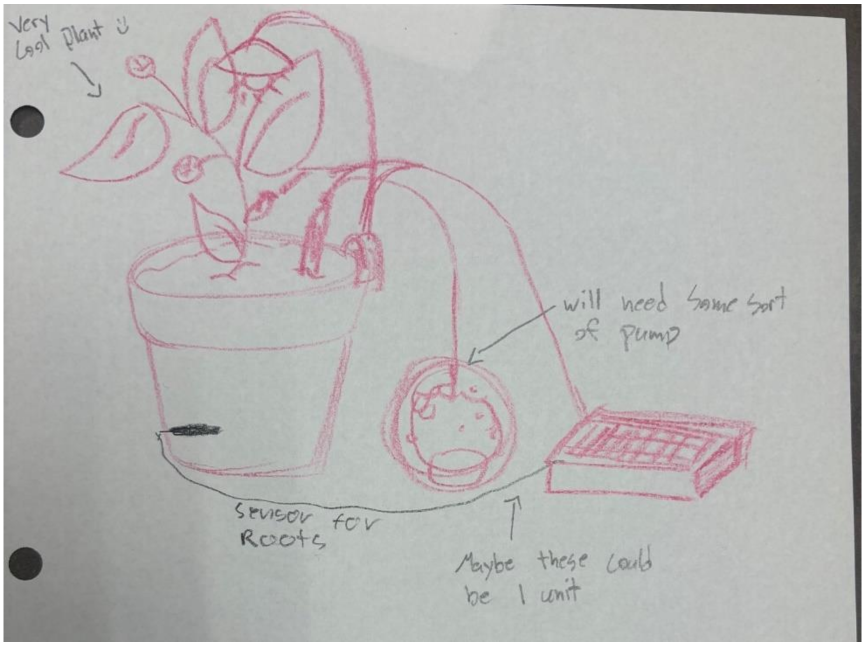
When brainstorming the best solution, the team produced various plant care product designs. Each of these designs had to not only cater to busy gardeners and keep the top-ranked user needs in mind but also consider the current budget, resource availability, and skill level of the team. At the beginning of the concept design process, however, these were not taken too seriously into account so as not to limit the creativity and brainstorming process.

The first design (A.1) depicts a singular plant in a pot with a plant grow light clipped to the edge of the pot, which then connects to an Arduino board which would be programmed to brighten or dim the light depending on the current light in the room. This would increase sustainability and efficiency. This concept also illustrates a water container connecting to a pump that leads to a sensor protruding from the soil. This sensor goes deep into the soil and indicates whether the soil is dry or not and allows the plant to source water from the pump if it is.

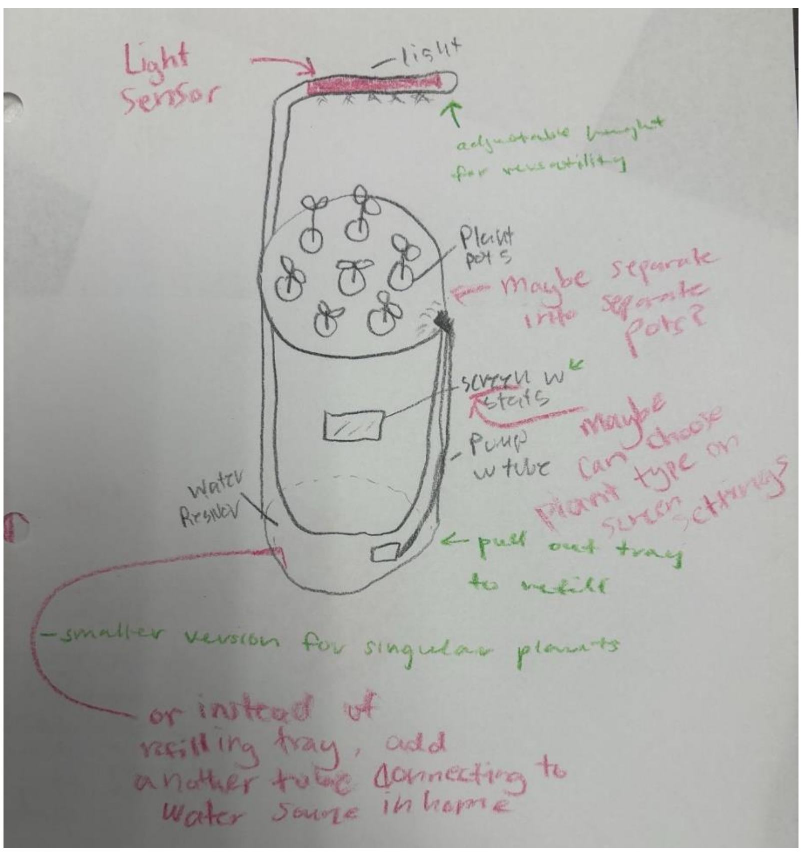
The second design (A.2) portrays another plant pot, though much larger than the previous, holding multiple plants. At the bottom of the pot, a water reservoir is installed and incorporated into a singular design along with the light and sensors, which make this a lot better visual-wise. It also makes it less of a hassle and takes up less space than the other designs. One of the ideas that was added to this was to create a screen display on the pot to allow the user to change the settings to specific plants' needs, increasing the versatility aspect of the product. This would also raise the overall price of the product and would require more skill to develop. This design would be durable as well if high-quality materials were used.

The third design (A.3) is very similar to the second, with all the functions incorporated into one compact design. The light stick is connected to the side with an Arduino board to sense the current light in the room, and the water basin is in the bottom part of the pot which can be pulled out to refill. The refillable aspect of the water basin, as well as the addition of the Arduino board, increases this product design's effectiveness. This concept, however, does not involve a screen which adds to the affordability rating.

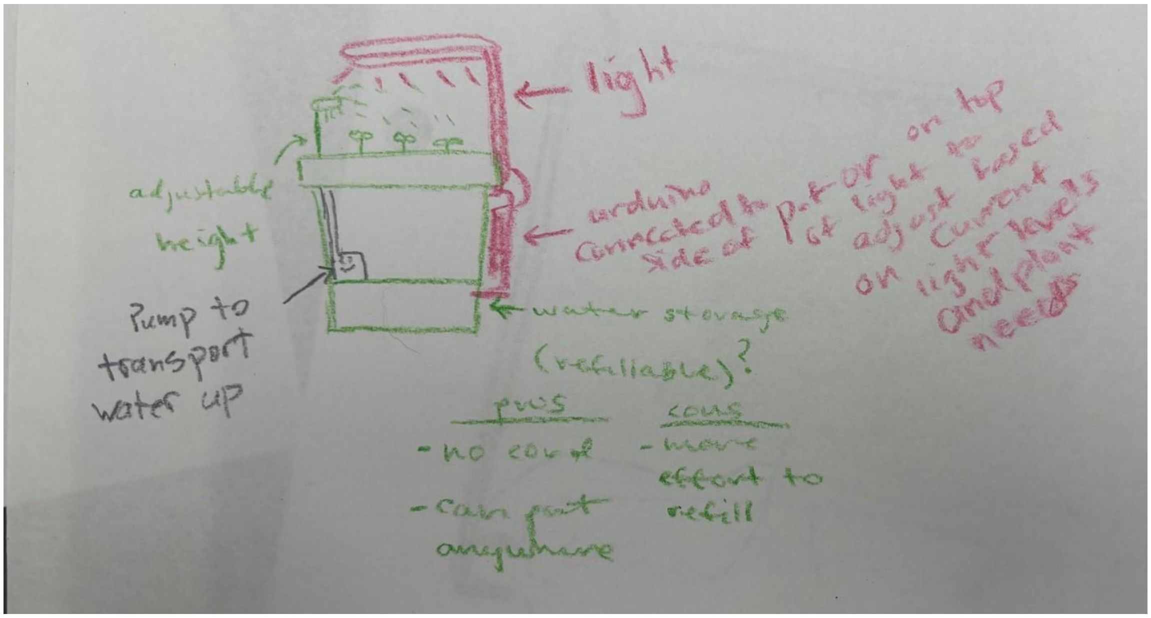
Lastly, the fourth design (A.4) contains the light and water reservoir elements as well. This design, however, lacks the Arduino sensor which takes away from efficiency and would manually have to be adjusted. The water reservoir is an external feature like the first design but resembles an IV and can be hung on the wall to save space. This also appears more aesthetically pleasing. This design also involves a display screen to show the water level the plant is at and the estimated time until the next watering.



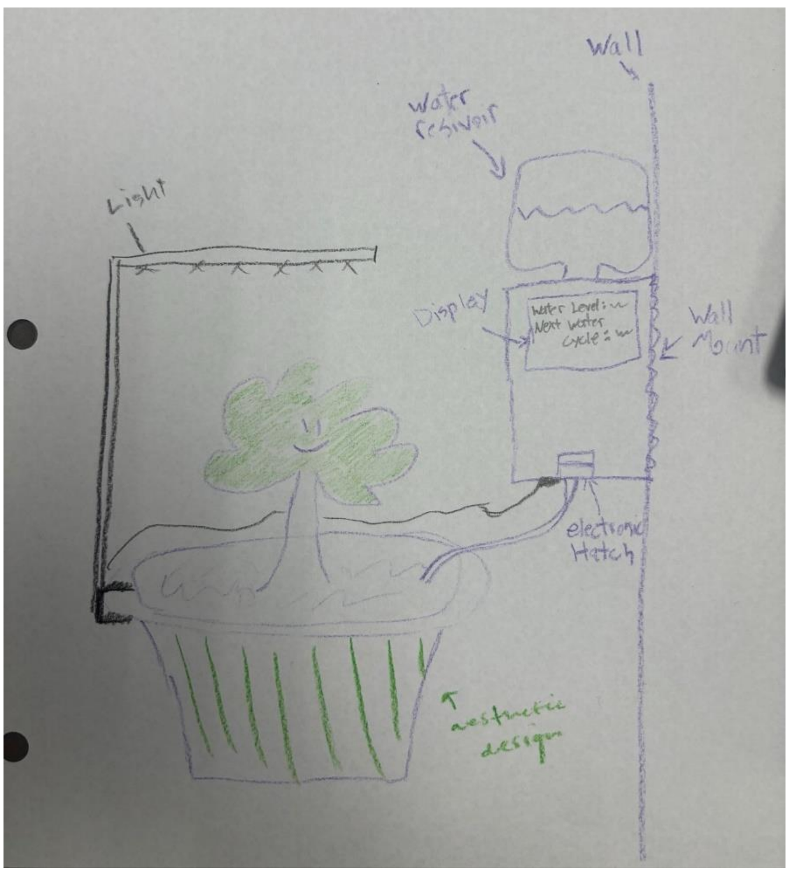
Appendix A, Figure 1



Appendix A, Figure 2



Appendix A, Figure 3



Appendix A, Figure 4

8. Concept Selection

a. Down-Selecting to Two Concepts

To narrow down the selection to the last two designs, the most important user needs, and the user feedback needs to be identified. The most important user needs that the Green Guru will be targeting, as determined in (B.3) include low maintenance, effectiveness, and durability. Additionally, some user feedback that was received based on the pitch video pondered the question: How will this product stand out from the hundreds of other similar products that are already on the market?

Based on these specifications, the two most viable options to move forward with are (A.2) and (A.3). Both designs feature a system that will be entirely internal and built into the plant's pot. This design is superior to an external model because it will be more aesthetic, easier for the user to manage, and complete its goal more effectively. It will also be inherently more durable because an external system would be easier to break as its components are exposed and vulnerable. These designs also feature a grow light or sensor which will help accomplish the user need of affordability.

Both designs will keep plants healthy while addressing user pains. For example, the systems will be completely automated, be programmable to different plant species, and eliminate certain conditions necessary for specific species. As a result of addressing these pains, user goals will be met such as more free time, less stress, and more diverse gardens.

b. Pugh Scoring Matrix

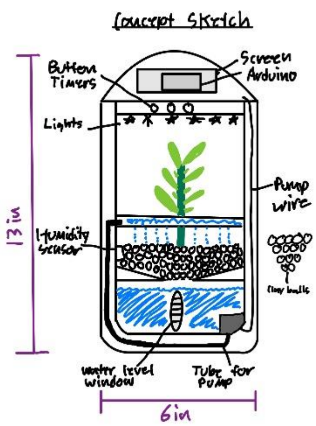
A Pugh scoring matrix compares a team's final concepts, and their user needs to a competitor's product. The matrix allows for the team to decide on which concept should be the final selection. The matrix below (see B.8) shows both the weighted score of Product Concept Design B (108.1) and Product Concept Design C (100.3). Both team members' concepts are also compared to a competitor's design. The competitor chosen in this matrix is the "LetPot System 2.0." The "LetPot System 2.0" falls short in versatility, receiving a rating of 3, Product Concept Design B is easily recognizable as satisfying the user need. With this information in mind, it is decided that the best concept for the team to use is Product Concept Design B.

		Reference		Concept 1 (Matt)		Concept 2 (Julia)	
User Needs	Weight (1-5)	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
High Quality	4	4	16	4	16	4	16
Low Maintenance	5	4	20	5	25	5	25
Effectiveness	4	4	16	5	20	5	20
Versatility w/ Plant	4	3	12	5	20	3	12
Aesthetics	2	4	8	4	8	4	8
Durability	4	4	16	4	16	4	16
TOTAL			88		105		97

c. Final Concept Selection

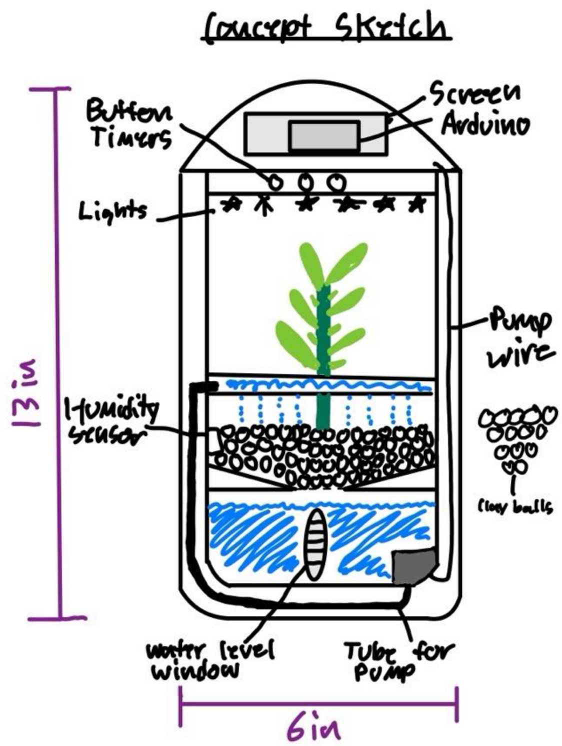
The final concept to base the product design on is Product Concept Design B (A.2). This concept best meets the design specifications and user needs while addressing the goals in "Down-Selecting to Two Concepts." Most of the justification for choosing this design is the same as the points discussed in this section because the designs are very similar. However, there are a couple reasons why this design had an edge over its counterparts.

To start, one of the main selling points of the product is its capability of versatility. By including the built-in display that was not featured in (A.3), the process of customization an**d changing setting will be much more intuitive and easier to navigate. The display will also open a window for adding a larger volume of plant species and settings, which will help the Grow Guru stand out from other products on the market. This design also scored highest on the pugh scoring matrix, which ensures that it addresses a high ranking of versatility better than any other concept.**



In addition to the screen, this design will feature a water reservoir built into the bottom of the pot, connected to a pump which will allow it to transport water up and onto the plants. There will also be an overhead grow light to ensure that plants will have enough sunlight to grow even in low-light conditions. This design will also be equipped with a light sensor to moderate the use of the grow light, and a humidity sensor inside the soil to determine soil moisture and distribute water accordingly. The improved, final version of the sketch for this concept (A.5) meets all the requirements for a successful plant care system for busy gardeners.

9. Grand Concept Design



The prototype displayed above details each element necessary for the proper functioning of the design. To begin with, the framework of the prototype conceals and protects the unattractive and sensitive inner components such as the Arduino board, breadboard, and wiring. This was done to increase durability, one of the main user needs, and works to increase the aesthetics of the product. Many similar products lack this quality because of exposed wiring and tubes that can be easily damaged. A gap between the plant's water basin and soil pot, and the frame allows for the design to run the water pump tube and wiring through the side tunnels. However, the wiring may not be long enough to reach the two boards which may also not completely fit in the roof of the design. Adjustments to the height and diameter of the product may need to be made.

The water pump connects to both the water tube and the pump wire. The watering tube leads up onto the soil's surface to move water from the basin into the soil seamlessly. The water then goes through the soil and waters the plant. Any excess water then sifts through the clay balls, through a thin filtering net and down back into the water basin. This ensures the plant is not drowned or overwatered and increases the product's functionality. Having the excess, unused water drain back into the water basin also increases the product's low maintenance quality so busy users can worry less about constantly refilling the basin.

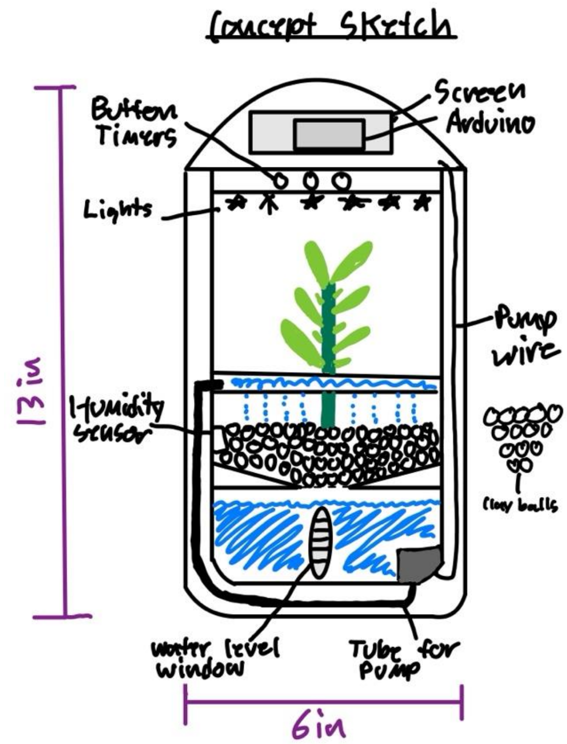
The wires go up through the side gaps in the framework and connect to the Arduino and breadboard. A neo-pixel light ring will be present at the top, connected to the Arduino and breadboard. Buttons are also present to allow the user to choose different timer settings for the watering intervals. Finally, a screen will also be connected to the Arduino and will display the timer for the watering cycle interval, temperature and humidity percentage. This allows the user to have a variety of plants in the plant pot. Some of these plants may need more or less watering, which can easily be done by the click of a button. Whereas many similar products usually are only built for the general plant needs and would water when soil is dry. Some plants that require dry conditions would be destroyed by these types of plant care systems.

However, the limitations in the breadboard and Arduino's pin locations may result in issues as some of the features of the product require multiple pin inserts of the same pin locations. And though the roof houses valuable functions such as the light source and two boards, it also limits the growth of the plant and would cap it once reached which was noted through user feedback. This would cause the user to have to either change pots or trim the plant, which are both unideal situations. The base of the design is predicted to be 6 inches in diameter and the height is 13 inches, though this is subject to change in order to address this issue.

During the creation process of the product, the team anticipates these challenges to alter the overall design. The product's size or roof design may have to change, and the location of the boards and the buttons may also have to be adjusted. The light source, watering, and different watering interval settings may have to be tested over multiple days with actual plants as test subjects. Once it is guaranteed to always be successful, this ensured quality may be presented and increase the overall feasibility of the design to users. The biggest quality, seen in the water system, settings, and drainage, would take priority in testing due to its highest competitive quality in the market for the target audience and the concealed sensitive innards. This would allow the product to gain exponential traction in the market because these features contribute to the most highly ranked user need, low maintenance.

10. Prototyping Design

a. Description of Prototype



The team intends to build the prototype using simple recycled materials, duct tape, and glue. Using these materials, the team intends to create accurately measured cut outs of the shapes present in the CAD model initially created. These shapes will be taped and glued together to create the base image of the CAD design. However, the plan for the initial prototype is not to develop and test functions and features, but rather to nail the overall size and visualization of the product because other features would use up valuable resources and cause issues due to the team's limitations in factors such as budget. The features of the design would not be able to be exacted without those materials such as the wires and screen and therefore would be impossible to otherwise bring forth in the prototype. This means that the initial product of prototyping would result in a low-level prototype.

The team anticipates that the resources needed from preliminary R&D to build the prototype include cardboard, tape, and other recycled materials that would be useful in creating a base structure. The cardboard will be used to build the main body of the prototype, though the team knows it will need to be cut up into smaller strips to create the prototype's cylindrical shape. In this way, the prototype will not be accurate because the plan is to have a fully smooth cylindrical base and the cardboard strips would create ridges in the prototype. As mentioned above, the prototype will not be accurate or able to test the product because of the complex design. The prototype will be an accurate representation of the product's size because the team plans to use the same dimensions for the prototype and the final product.

b. Prototype Design Requirements

Prototype Design Requirements	Range	Ideal Value
Product has different modes to support different types of plant needs	Working Modes (0 - 3)	3
Product is lightweight	Weight in lbs (5 - 15)	5 or under
Has a large water resevoir	Reservoir Size in Ounces (1 - over 4)	at least 4
Product is affordable	Price in Dollars (75 - over 150)	no more than 75
Takes a reasonable amount of time to maintenance	Maintence Time in Minutes (under 10 - 25)	10 or under
Electronic components are functioning	Working Components (0 - 4)	4

The team will use these design requirements to fine tune the final prototype as it is being built. If the team notices that a certain aspect of the prototype does not meet these requirements, they will continue adjusting the prototype to meet them. Similarly, the team will use these requirements to gauge when the prototype is fully finished.

c. Testing Methodology and Verification Plan

Throughout the testing process, the product will undergo a multitude of trials and will be assessed based on the functionality of the different watering interval settings for product versatility, weighing of the product for the lightweight quality, measuring of the water basin' capacity for low maintenance, overall market price calculation and similar product price comparisons, user usage of the product to find the average maintenance time, and overall system functionality. These trials will reflect the top user needs and will verify if the product has met the requirements of being low-maintenance, effective, and durable and will be represented numerically on the scorecard presented below.

The three different buttons on the device should each be encoded with a time interval between watering the plant. The screen should display the amount of time until the next watering is to occur. This will be a key element in calculating and testing whether the time intervals, displayed in hours, are correct and if each setting truly waters when at their exact watering hour. Therefore, this should require 6 different trials. One to check whether the button is active and functions per each button which makes 3 trials. And another one to check whether the interval between the waterings is correct in hours between each button, which makes another 3 trials. Once these trials all pass the test, this will ensure that the product encapsulates high versatility and can accommodate multiple species of plants.

The next test should be simple. Only 1 test is required, but for best accuracy the product, with the plant, water filled basin, and soil, will be weighed 3 different times on a scale. The weight will then be averaged to find a more precise weight measurement in pounds. The goal is for the product to be lightweight so ensuring that it remains under the limit of 5 pounds is essential to the success of the product. The design will be altered if this requirement is not met.

Ensuring that the product is low maintenance is the top quality that users are looking for in this product. Therefore, if the water basin can hold plenty of water and does not have to be replaced or replenished by the user often this factor will improve. To make sure this is the case two different methods can be applied in two different trials. The first trial will involve measuring the water basin's area in cubic inches. This can then be converted to fluid ounces to find how much the basin will be able to hold. The second trial can be a more involved and simplified method of simply pouring water into the basin ounce by ounce and seeing how much it can hold.

Next, to guarantee that the product ranks the expected amount for affordability, two different methods must be applied. A calculation of how much the product costs the team to build in USD must be made by adding up the material cost and labor cost (to put into real world perspective). This overall price will then be compared to similar product prices on the market.

Going back to increasing the product’s low maintenance quality, a couple user test runs of the product should take place. Specifically, 5 different types of people, preferably with no engineering experience, will participate in 5 different test runs of the product. The time, calculated in minutes, should be recorded via a stopwatch for each person’s test run of how they would maintain the product, with no previous experience or instructions. These test run’s times will then be averaged to find the overall test run time and will be compared to the predicted time. If it does not meet the requirement, adjustments will be made to the design until it can be verified against the requirement.

Lastly, the product needs to be effective in completing the task it was designed for. Therefore, every feature and component included in the product must be entirely functional and working properly. To ensure this is the case, the LCD screen, watering interval buttons, humidity sensor, water pump, and the water tube should all have no errors within their systems, coding, or functioning. For example, the water tube should not be punctured so the water doesn’t run through it properly. The LCD screen should display the necessary details of the system including the hours until the next watering and humidity level. This information should be manually recorded to compare and see if the screen is displaying the correct information. The buttons should each be encoded with their corresponding settings and if pressed should change the watering time intervals. The humidity sensor should be calibrated and functioning. And the water pump should be checked to see if it is also pumping water out to the soil. These tests and recording how many components are functioning allow visual data for how effective the product is.

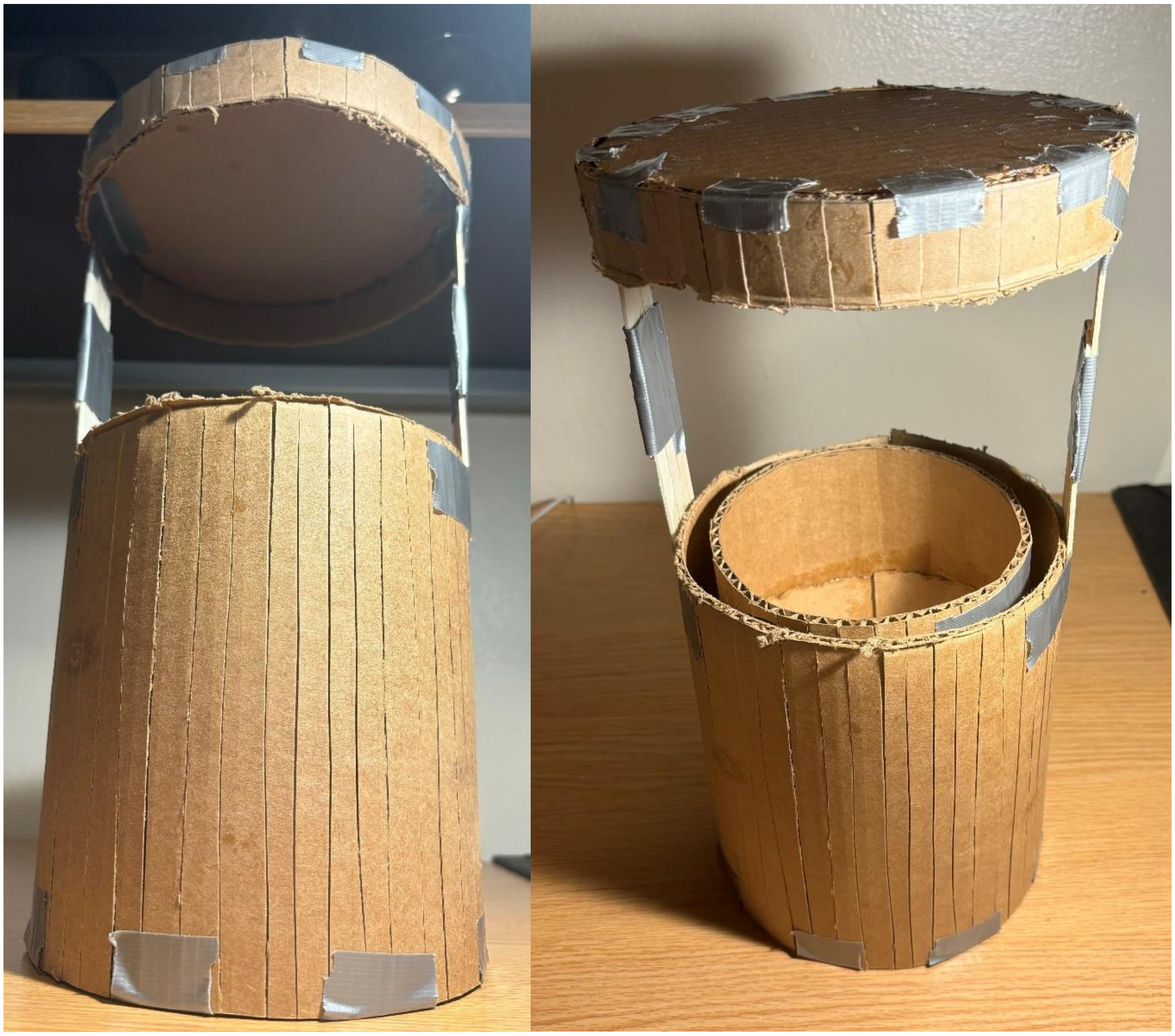
Correlation Matrix and Verification Scorecard

Design Requirements / User Needs Correlation Matrix								
	Product has different modes to support different types of plants	Product is lightweight	Has a large water resevoir	Product is affordable	Takes a reasonable amount of time to maintenance	Electronic components are functioning		User Need Weight
Low maintenance	3	3	9	0	9	0		4.5
Effective	3	0	3	3	3	9		3.6
Durable	0	0	0	3	0	0		3.4
High Quality	0	3	3	3	0	9		3.9
Versatile	9	3	3	0	3	3		1.8
Affordable	0	3	0	9	0	0		1.9
Aesthetic	0	0	0	0	0	0		1.5
Importance ->	40.5	36.3	68.4	49.8	56.7	72.9		

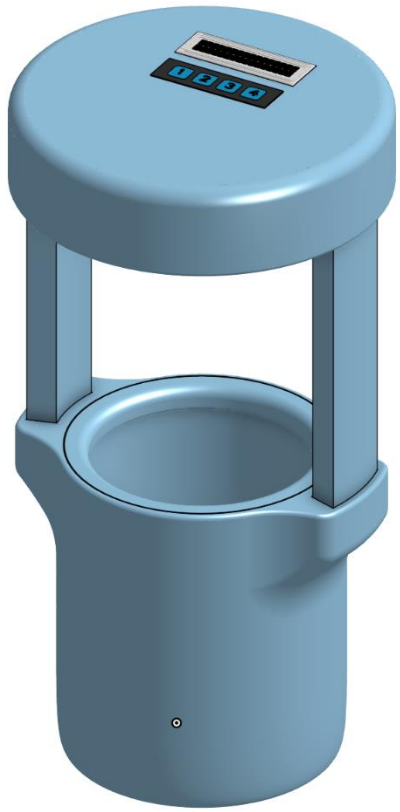
Scorecard					
Requirement	Range			Score Rubric (full credit)	Score
Product has different modes to support different types of plants	**0/3:** No functional modes	**1/3:** 1 mode is functional	**2/3:** 2 modes are functional	3 functional modes are present	3
Product is lightweight	**0/3:** More than 15 pounds	**1/3:** More than 10 pounds	**2/3:** More than 7 pounds	Product is under 5 lbs including water, soil, and plant.	3
Has a large water resevoir	**0/5:** at least 1 ounce	**2/5:** at least 2 ounces	**4/5:** at least 3 ounces	Resevoir can hold at least 4 fluid ounces	5
Product is affordable	**0/4:** Under $150	**2/4:** Under $125	**3/4:** Under $100	Production cost is under $75	4
Takes a reasonable amount of time to maintenance	**0/4:** Under 25 minutes	**2/4:** Under 20 minutes	**3/4:** Under 15 minutes	A maintenance session can be completed in under 10 minutes	4
Electronic components are functioning	**0/4:** 1 or less component functional	**2/6:** 2 components functional	**4/6:** 3 components functional	LCD screen, Buttons, Humidity sensor, and Water pump all functioning properly	6

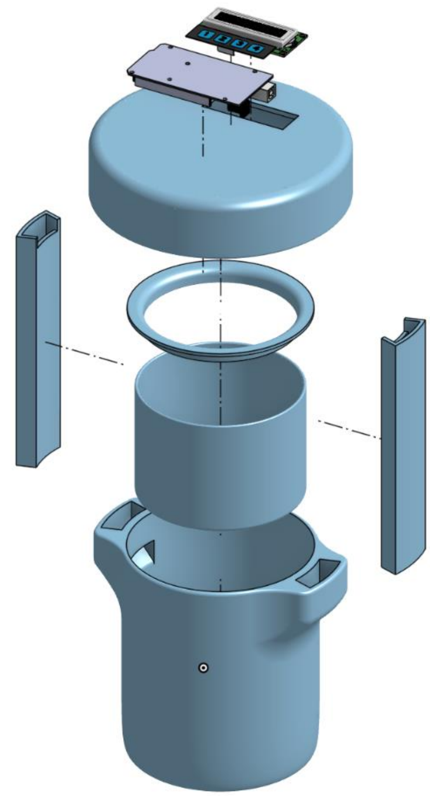
d. Prototype Preliminary Design and Mock-up

The mockup for the Grow Guru was created out of recycled materials, glue, and duct tape. Although this mockup is completely non-functional, it was made to be as accurate as possible to the preliminary CAD model. The purpose of this mock-up is to better visualize what the product would look like and make any necessary changes. Based on the mockup, it was identified that the roof needed to be raised a couple of inches to allow easier access to the plant basin. The team also noticed there needed to be a rim between the outer cylinder and the inner insert for the plant basin to fill the gap. Lastly, the team was able to physically place components on the model, including the Arduino, LCD screen, and breadboard. Through this process, it was discovered that there was not enough space on the underside of the roof to fit all the components. In order to solve this problem, another piece will be added underneath the components that the breadboard can sit on top of, and the neo pixel grow lights can be mounted underneath of it.



Prototype Design – Preliminary Cad



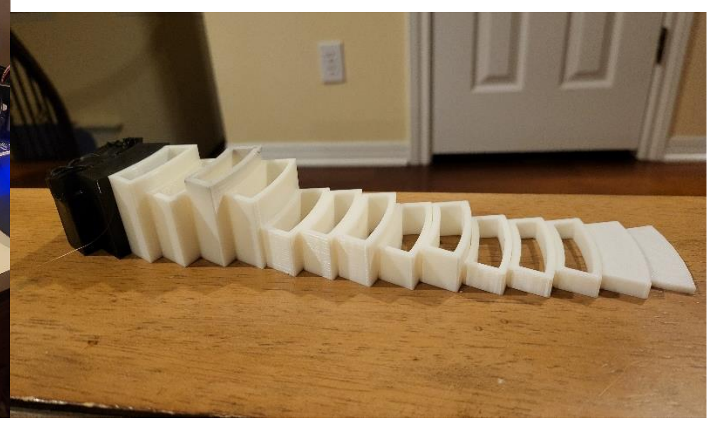


Detailed Design Review

11.Prototype Fabrication and Evolution

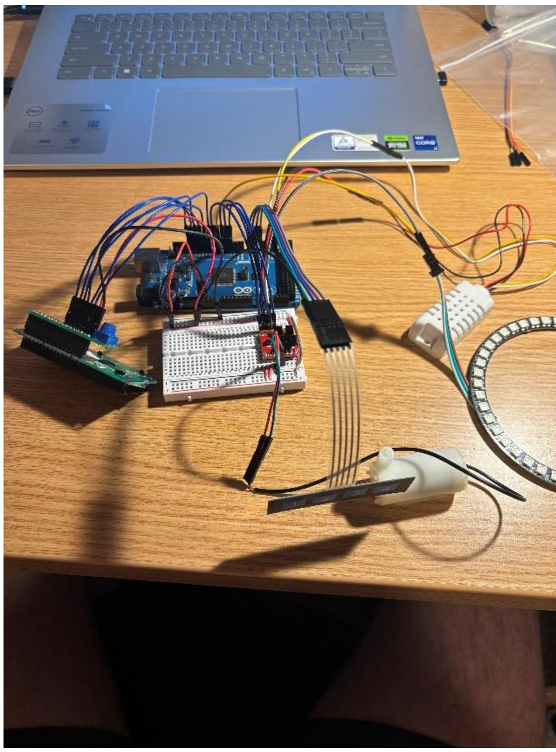
a. Progression of Building and Testing

For the most part, the prototype was built from a top-down approach. The entire final design for the prototype was put together before any building began, as shown in the prototyping design section. This made the actual building much simpler because it only required following a plan that was already laid out. Building began with assembling all the 3D printed parts and ensuring tolerances were correct.

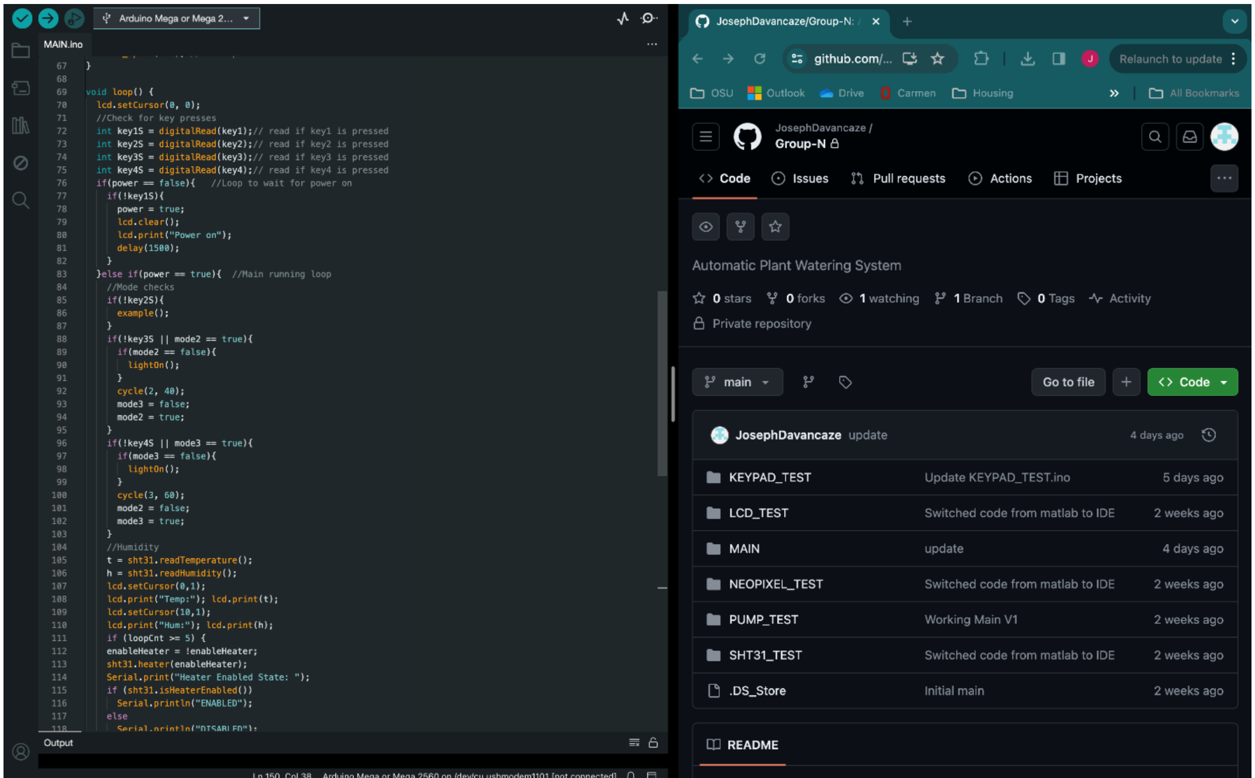


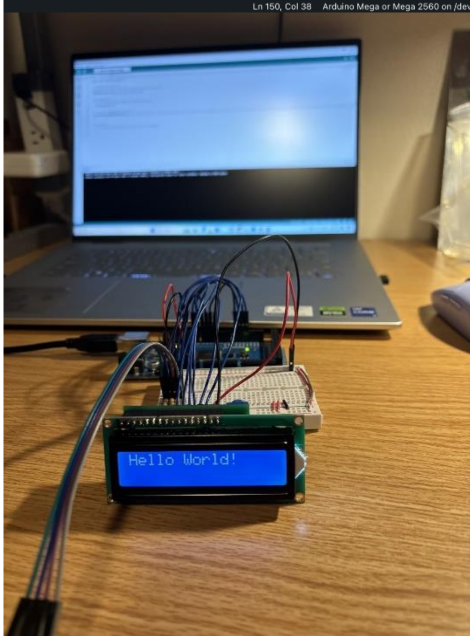
The arms connecting the pot to the upper control section took quite a few iterations because they tended to be too loose and rattle due to the weight that they were responsible for supporting. Eventually, all 3D printed parts were complete and able to be fully assembled.

The next step in the progression was figuring out the wiring that would connect all the components to the Arduino. This proved to be very challenging because certain components required certain parameters to work correctly. For example, the pump needed a motor driver chip which had to be put on the breadboard and required additional wiring. Also, the humidity sensor needed to use SDA/SCL pins on the Arduino instead of PWM pins. The documentation provided for wiring these components was often inaccurate or did not work for the purposes needed. As a result, it took many iterations to figure out.



To test that the wiring for the components was right, it was necessary to write a program to Arduino that could confirm that components would function properly for both desired inputs and outputs. Originally, the team tried to use Matlab with an extension for Arduino. However, after a week of research and testing, it was clear that there was not enough documentation for it to accomplish what was needed, assuming it was possible in the first place. As a result, the team decided to switch to using C++, which had a lot more documentation for Arduino and was more straightforward. Arduino IDE was also used to connect and upload the code to the board. First, initial test scripts were made to help the team figure out how to program each component individually, before compiling everything into one algorithm. This process was very successful and through a little bit of research, the team had a good understanding of how each component interacted with the code, and what would need to be done to have everything work together. Finally, with the test code, initial algorithms were written where the components could be tested together. After this was done successfully, it was possible to complete the final algorithm that would run on the Arduino.





Lastly, now that both the 3D-printed parts and the electronic parts were complete and functional, all that was left was to assemble everything. Fortunately, the CAD design implemented many features to make this as simple as possible. There were pegs to hold in the breadboard and Arduino, a slot for the pump to clip in to, holes and channels for the wires to path through, and pins to hold the top assembly in place. After gluing all the components in place, pathing the wires correctly, and putting components in place, the prototype is almost complete. All that remains now is putting the soil pellets inside the basin and planting the first plant so that some of the tests which could not be completed previously can begin.

b. Research and Development

The research and development that was necessary to create this prototype included the circuit wiring, code, and conditions needed for plant growth.

For the circuit wiring, many of the diagrams provided from the microcontroller's lab manual ended up working for the application that was needed. The main issue when it came to wiring was with the keypad. The documentation that was provided was meant for Matlab, but it did not take into account that Matlab could not activate the built-in resistors on the arduino that were necessary for the keypad to function correctly. Initially, additional resistors were implemented onto the breadboard to solve this problem. However, this was very bulky and required four additional jumper wires. Luckily, this problem was resolved when switching to Arduino IDE, and the internal resistors on the board were able to be used.

The coding process was very tedious and time consuming. A lot of time was wasted trying to use the documentation that was provided for Matlab, only to realize that it would not work out. The switch to C++ made things much less complicated, but there was no documentation provided for it, so the methods for the code had to be found entirely from the internet. The research for this consisted of a whole lot of google searches and YouTube videos. After a while, it was found that there were built in libraries for most of the components being used that were built into the Arduino IDE program. These libraries were downloaded onto the Arduino and allowed the code to work properly. Additionally, the libraries included example code that was able to be implemented into the final algorithm with a little bit of tweaks to configure the code to the application that was needed.

Lastly, the components needed to be configured to be the best for sustaining a plant's life. The two ways that this was possible were through watering and lighting. For the lighting, the team found that the best way to use the neo pixel light was by alternating 3 different RGB values across the ring. These values are (84, 64, 255), (255, 0, 0), (163, 255, 0). For watering, to make the prototype as versatile as possible, there are 3 different modes that will water the plant once the humidity reaches below a certain value. The values for the humidity threshold are 40%, 60%, and 80%, to allow for use between plants that have different watering needs.

With preliminary testing, it was concluded that all components are functional, the prototype can support different types of plants, and the production cost of the prototype is under $75. In order to test the rest of the requirements, the protype needs to be assembled fully including water, soil, and the actual plant.

c. Compromises

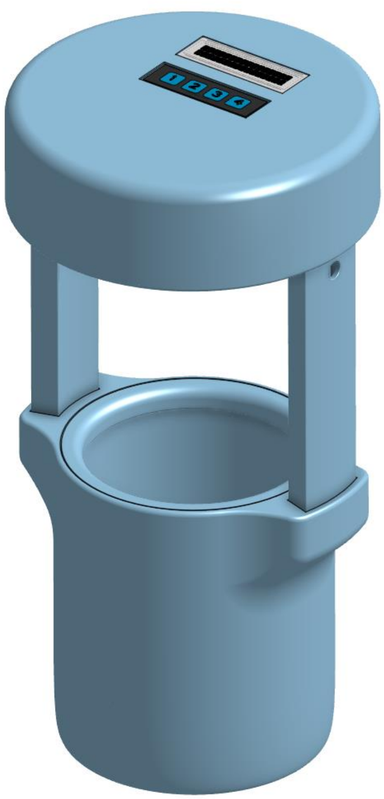
Because the plan for this prototype was very straight forward and laid out a head of time and the team worked very diligently to make everything happen, there were few compromises that had to be made.

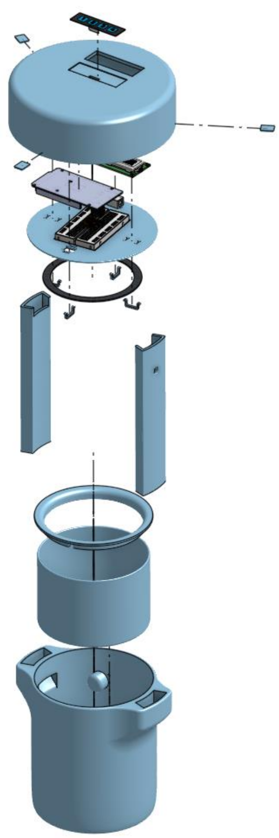
However, one compromise that was decided was eliminate a potential component that would sense if the light was on. This component would act as a failsafe, in case the light failed to turn on, it would hardcode it to turn on as intended. The team decided that the marginal utility of adding this was not enough to warrant doing it. It would take up additional wiring space, and there was no good spot to put it. As it turned out, the light works perfectly every time, and this component would not have been needed.

Another compromise was deciding between using soil or hydroponics. The drawback to soil was that it would get messy and get all over the place, while the drawback with hydroponics is that it would be harder to do correctly and would make the prototype more fragile overall. The team decided to use nutrient-enriched clay pebbles in place of soil. This compromise solved the mess from soil and kept the prototype simple enough to be accomplished.

12.Detailed Design

a. Final Prototype Design





The final design prototype matches the research and development findings discovered by the team in many ways. A top priority of the design ranked by the user needs was being low maintenance, and the design accomplishes this effectively by having a large water basin and automatic lighting. Another top priority discovered in the research phase was the effectiveness of the prototype, which does this by constantly checking humidity levels within the growth mixture and adjusting the watering accordingly. Lastly, the design encompasses versatility, thus it has a larger area for plant growth to accommodate a variety of plants as well as different cycles depending on each plant's specific needs. In order to satisfy these user needs, the design features many non-standard parts, such as the entire plastic housing, which was built from the ground up to meet the needs.

A few design considerations that could be implemented in the future include having various sizes of planters and having more humidity level options. Being able to produce multiple sizes of planters helps exceed the goal of versatility as this allows it to be placed in a variety of new places that the design currently does not fit. In addition, having different humidity level choices and the option for the user to input a custom number, allows for more flexibility across different plant types.

b. Revised Grand Concept Design

After building, testing, and revising the prototype, there were no necessary changes made to the design concept. The challenges that the team ran into while creating the prototype were mainly physical or practical, not conceptual. While prototyping, there were a few 3D-printed components that did not fit during assembly. To fix this problem, the team worked in the tool shop to file down pieces that had incorrect tolerances. Also, the clips made to hold the LED in place were replaced with paper clips found in the tool shop. These paper clips could be replaced with short wires in the actual production of the product. These minute fixes, however, did not change the overall grand concept design. The team was able to keep the original grand concept design as it was initially created because there were no incidents where the design failed while prototyping.

13. Final Prototype Verification

The final verification testing provided insight into the functionalities and dysfunctionalities of the design. To summarize this information on the final Grow Guru prototype, each element was analyzed based on quality and rated out of 6 points which allowed for an easy overview of the strengths and weaknesses.

To begin with, the watering capabilities of the Grow Guru was rated 4 out of 6. The watering functions and it waters the plant like it is supposed to, however didn't receive a full score due to its lacking range in water dispersion throughout the pot. The reason for this was discovered to be due to having a low water pressure.

Next, the versatility of the product was assessed and rated 5 out of 6. The device has multiple functioning water cycle modes and options for the user to adjust the watering intervals for diverse species of plants. However, a single point is missing because there could always be more modes added to the device to cater to specific species of plants' needs.

Low maintenance received a full score of 6 out of 6 due to its self-watering, self-sustaining feature as well as not needing often refilling due to the drainage of excess water back into the basin.

Effectiveness received a 3 out of 6 due to the water pressure issue mentioned above, the overhead light being bulky which could be simplified to a light bar, and the water level of the basin not being visible. This last issue especially takes away from the product's effectiveness because if the water level is not visible from the outside, the user cannot know when it will need to be refilled unless they take out the top portion which can be time consuming and tedious.

Lastly, aesthetics ranked 2 out of 6. Although the design is sleek and hides all the unattractive internal components, it can also be bulky, which might prove unideal for a user wanting to decorate their home with aesthetic plants. This design could be simplified to accommodate for that.

14. User Validation

a. Top Three User Needs

The three highest ranked user needs have been identified as low maintenance, effectiveness, and versatility as determined by the pairwise comparison chart displayed in the team's research results.

Low maintenance has been ranked as the most important user need (with a score of 5 on the pairwise comparison chart) because the product was initially designed for gardeners with little time to take care of their plants due to their busy schedules. The product can be considered low maintenance if the user reports a minimal amount of time spent maintaining their plants.

Effectiveness as a user need describes how well the product can care for the user's plants. The team found effectiveness to be an especially crucial user need (scoring a 4.4) because, as is with any product, a product that does not perform its job well is unsuccessful. If a user reports their plants as healthy and thriving because of using the product, the product has been effective at satisfying the user's need.

Versatility has been ranked as the third most important user need (scoring 3.9 on the pairwise comparison chart) due to the team's belief that a successful product should be multifunctioning. If the product is determined to be versatile, it will be able to support the needs of several different types of plants to grow healthily.

b. Goals

To ensure that the goals of having the three top ranked user needs of low maintenance, effectiveness, and versatility are met, users will participate in test runs of the product. The data retrieved from these user tests will be used to address any issues or concerns and validate the usability of the product and overall success.

The goal is to receive constructive feedback on the product that can be used to improve the design and determine whether the following questions can be answered:

- Can users achieve the task and are their needs met?
- Does this product save the users time?
- Are users satisfied with the product and the versatility of it?
- Do users see this product competing well with similar products on the market?

The plan for obtaining such information involves a series of tests, user ratings, and final evaluations. Users will be given the product with minimal instruction for how to use it to test ease of use, which goes along with low maintenance. The plant, water, and clay pebbles will be provided beforehand, however. Users will then be analyzed on how they utilize the product and notes will be recorded on the secondhand experience observed. They will lastly receive two surveys. The first will be the scorecard which they will be able to fill out anonymously and the second will be an experience related survey, asking questions on what they enjoyed, what they disliked, concerns, and a section where they may rate the effectiveness of the product's different functionalities on a scale.

Results and data collected from different participants will be compared to find commonalities in concerns and the most desired improvements which will be prioritized. Final evaluations will occur based on this data and adjustments will be made to the product accordingly. This method of user validation and testing is highly effective because firsthand experience and feedback can allow the designer team to quickly adapt and further develop the product's lacking areas.

c. Methodology

The user need for low maintenance can be tested both through internal tests and through user feedback. The maintenance process will consist mainly of refilling the water reservoir, and occasionally switching out the soil pellets. The team can conduct multiple tests in house with different members to determine the average maintenance time. This statistic can also be compared to initial user surveys to determine if the maintenance time is within the allowable threshold.

It will be tricky to determine effectiveness, because this will be subjective to each user and dependent on the type of plant they are using with the product. As a result, the only way to measure effectiveness will be through user reviews and surveys. In the initial user surveys, there will be a section requesting a 1-10 rating of effectiveness with room for additional comments. There will also be an opportunity for reviews to be posted on the website or amazon page where the Grow Guru is launched. If the mean rating for effectiveness is above a 7/10, the product will be considered effective in most cases. Below this threshold, the team will read through user feedback and possibly revise the initial design.

To evaluate versatility, the team will test the product's ability to sustain 50 different types of common household plants and herbs. Using the mode out of the 3 that is most suitable for the specific plant, the team will rate the products' ability to sustain, take care of, and grow the plant on a scale of 1-10. Once again, if the average rating is above a 7/10, the product will be considered versatile enough to be an effective market competitor.

d. Ethics

The team prioritizes ethical data collection within research. Data will only be collected from willing participants and will remain anonymous. This ensures user privacy is respected throughout the research process, as no private information will be collected and any potentially identifying details will be anonymized before analysis. In addition to that, end users will be informed of what data will be recorded and how their feedback will be used. These steps will be taken to protect end users during this research phase.

15. Value and Impact

a. Stakeholder Value Matrix

	A	B	C
1		Value Categories	
2	Stakeholders	Economic	Social
3	End Users	*Economic impact, positive, on end user due to providing a cheaper option on the shelves compared with other products on the market*	*Social impact is positive on the end user because the product being cheaper provides more accessability and equality among low income users*
4	Distributors	*Economic impact is positive on Distributors. The positive impact involves that they will have a cheaper, high quality product to sell which increases the buying rates.*	*Social impact, both positive and negative, on Distributors. Positive due to the increased accessability of the product but also negative due to having to take the time to investigate ethical considerations or deal with customer service regarding the product*
5	Designers	*Economic impact is positive on Designers due to increased number of jobs available.*	*Social impact, both positive, on Designers. Positive due to creating a product that is helping a lot of people.*
6	Communities	Economic impact is positive on Communities due to having cheap option of self watering plant system.	Social impact, positive due to the potential to become something bigger and become an irrigation system for crops for communities.
7	Investors	Economic impact is positive on Investors due to the high chance of the product being sold on the markets	Social impact, positive if investors are interested in environmental support, plant growth and health, and user happiness.

b. Economic

The stakeholder value matrix provides insight into how the end users, distributors, designers of the product, communities, and investors will be affected economically. Positive impacts were mainly noticed throughout the analysis.

Using the budget and expense tracking, it was found that the end users should be positively impacted by the product. This design cost $63.96 in total to make. This includes $3.00 for the water pump, $5.00 for the LCD Screen, $3.00 for the humidity sensor, $6.99 for the clay pebbles, $15.00 for the Arduino, breadboard, and wires, $3.00 for buttons, $12.99 for the neo-pixel light ring, $5.99 for the mod podge sealant, $5.99 for metal mesh, $3.00 for the motor driver chip, and some for reprints which would not be considered into the final cost for the final product due to exacting the measurements during the test prototype design stage. Compared to similar products on the market, this turns out to be a cheaper and therefore more accessible option while still maintaining the high-quality aspect of it. Other products with the same functionalities of the Grow Guru typically range from $80 to $200, depending on the quality. Maintenance costs for this product will likely be very miniscule as the product will only need to be refilled with water to continue its job with no other interferences. Of course, if the product requires repairs after damage, this cost would be directed to an outside repair source, which would account for manual labor as well, rather than through the design team's choice of pricing on the product.

This cheap, high-quality aspect of the product not only increases accessibility but also knocks out having increased consumer rates like a line of dominos. For the distributors this means increased sales, revenue, and consumer activity in their wares, which provides them with a positive opportunity. The product will also likely be self-sustaining and not require any subsidies due to the already low-price tag.

Designers will be positively impacted by this because of high sales of their design which will also lead to more job openings and economic opportunities. Communities will be positively impacted because of the potential for this product to become a part of a larger project: an irrigation system for gardens or crops. Repairmen will also gain more job opportunities when having to repair the damaged product.

Investors will likely have an eye out for this product due to its high potential for success in the market. The low-price tag, durability, versatility, effectiveness, and low maintenance qualities will draw in consumers and increase the chances of the product landing well in the market and being sold.

c. Social

The stakeholder value matrix outlines how end users, distributors, designers, communities, and investors will be affected socially because of the product. As seen in the stakeholder value matrix, there are many positives and a few negatives associated with the product's social impact.

For end users, the social impact of the product is positive due to its affordability. The product will be accessible to many users including those that may have lower income, therefore providing an equal opportunity for all potential users to benefit from the product. Designers are also expected to receive a positive social impact because the product is an opportunity for designers to contribute to a project that will help those in and out of their community. Similarly, investors will see a positive social impact if they are interested in supporting the environment and healthy plants along with user needs. With the potential growth of the product to include irrigation systems for larger crop fields, there is a positive social impact on the communities surrounding these fields. Although the product is currently designed to fit individual plants, the team has considered the possibility of designing larger pots to include the needs of users with a large amount of plant life to care for. Many farms with such crops help to support their communities and as a result, the product would be positively impacting these communities. Lastly, distributors would be the only group to see both positive and negative social impacts. Distributors will be able to increase accessibility for users, though as a result, they will also need to take the time to investigate their ethical concerns and facilitate customer service regarding the product. Though they are negative, these social impacts are very common for distributors when considering almost any product.

An unintentional social impact that the product could likely cause is an increase in waste in landfills and/or the environment. Because it is up to the discretion of users to dispose of packaging, it is difficult to anticipate this aspect of the product's social impact. A potential solution to this problem could be the addition of a warning on the packaging for users to practice responsible disposal of any waste associated with the product.

16. Project Recommendations and Next Steps

After finalizing the design, putting it to tests, and understanding each of its weaknesses, many recommendations and next steps were identified for the future of the Grow Guru.

A better, more high-tech screen should be implemented into future designs of this product to allow for the device to cater to a vast variety of plant species and increase its versatility on a larger scale.

Speaking of scale, in the future the team also plans to create alternative sizes to allow for different sized plants to be cared for using the product. Alternate colors will also be available to increase user interest and the aesthetic quality of the Grow Guru. This will expedite the growth of the product in the market.

It was also determined that in the future, this product shall have its water pressure improved to increase the overall range of the water dispersion. Doing so would achieve better effectiveness of the product and would be helpful toward a goal for even farther in the future which would be to develop this product into a solution for community irrigation systems. This would prove beneficial to communities, farmers, and crops across the globe and may even aid the global hunger crisis.

There are various ways the Grow Guru can develop and be used to solve issues all around the world, big or small.

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Appendix A. Evidence of Brainstorming

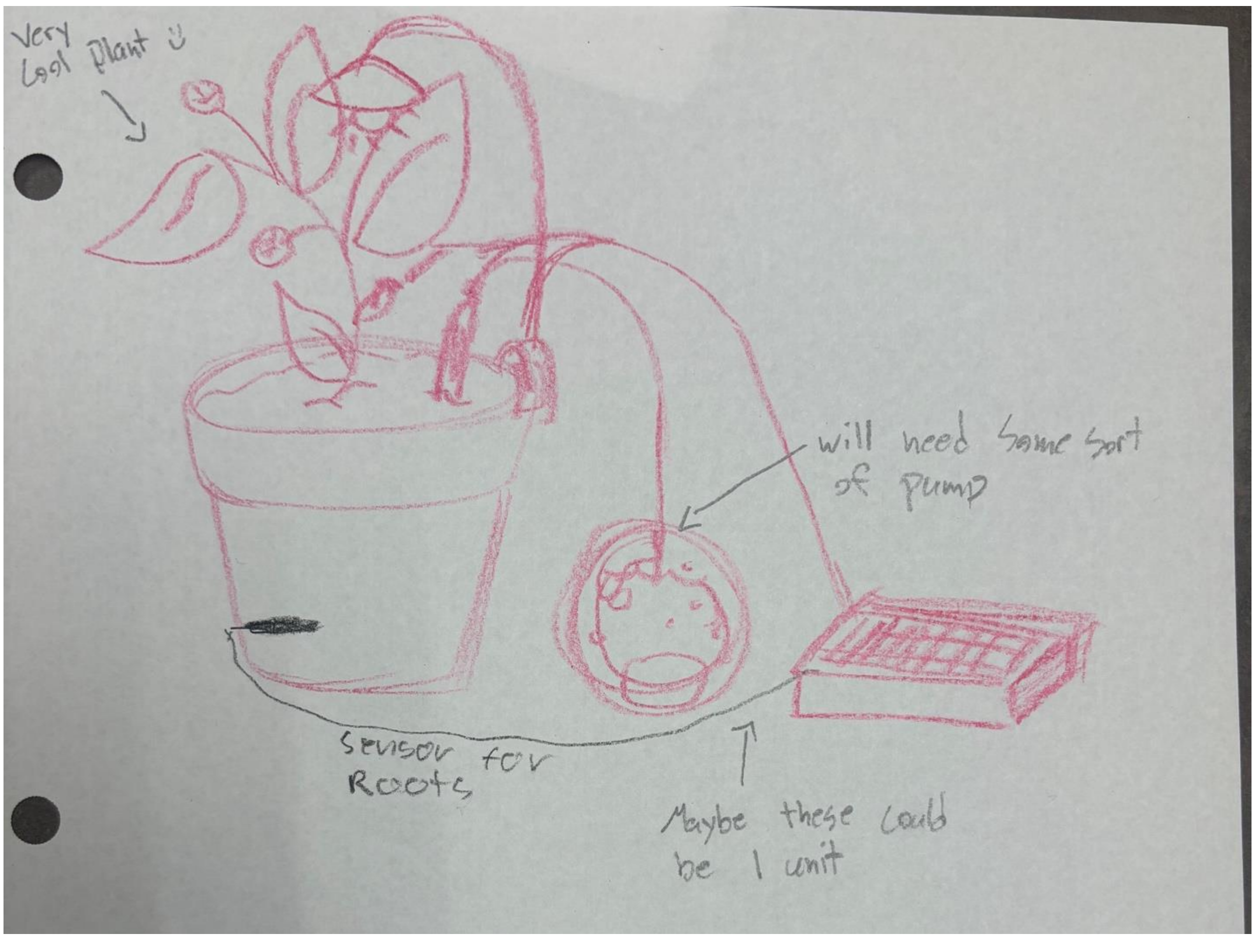


Figure 1 Product Concept Design A

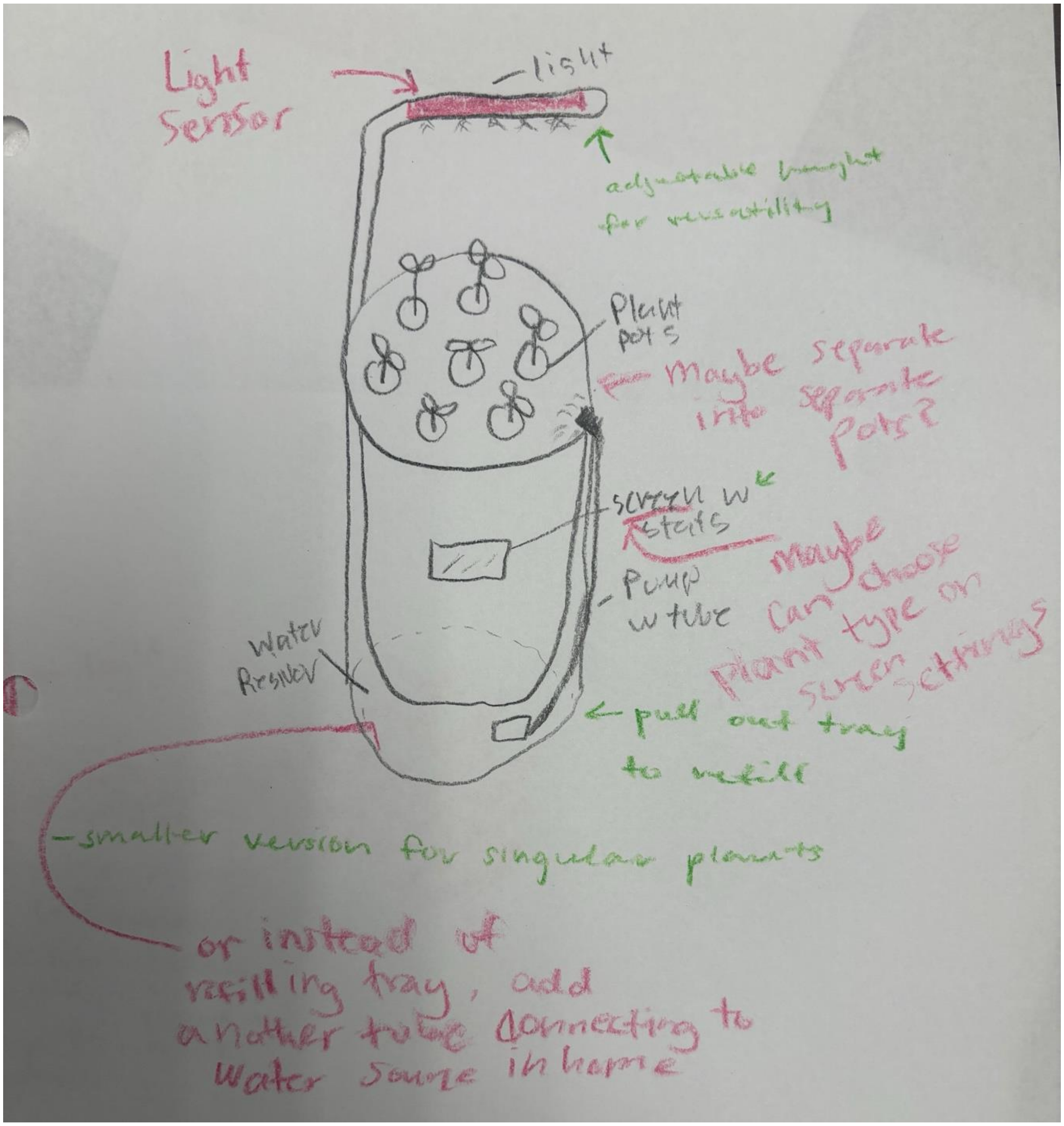


Figure 2 Product Concept Design B

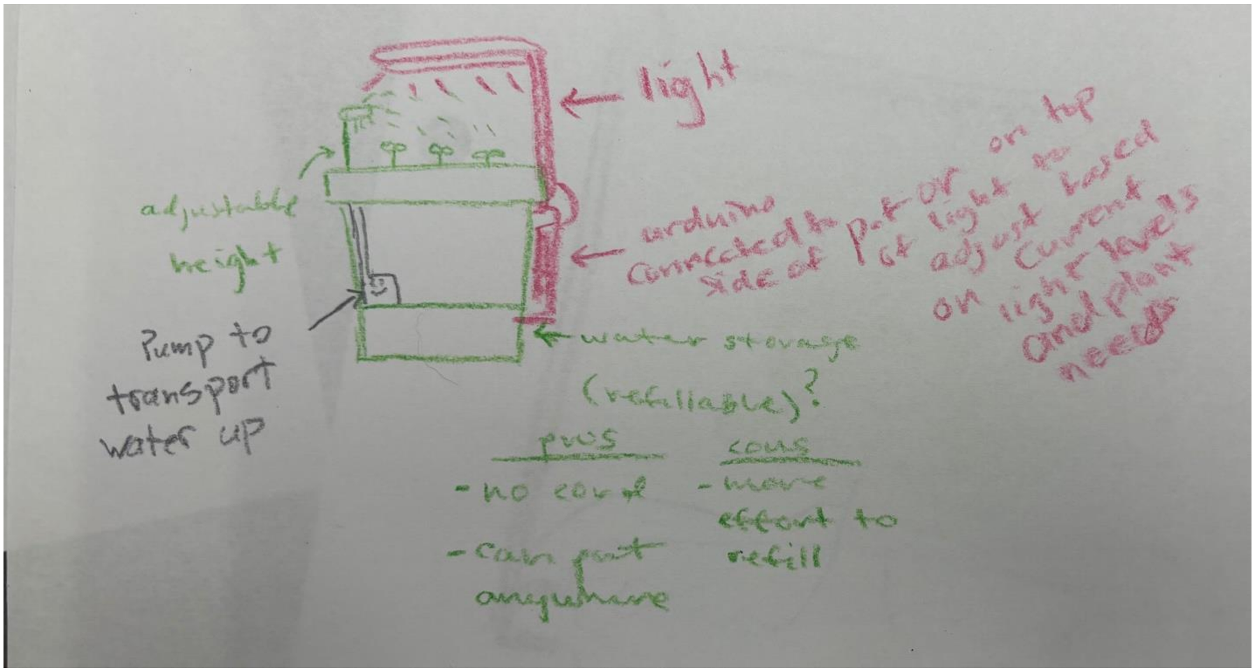


Figure 3 Product Concept Design C

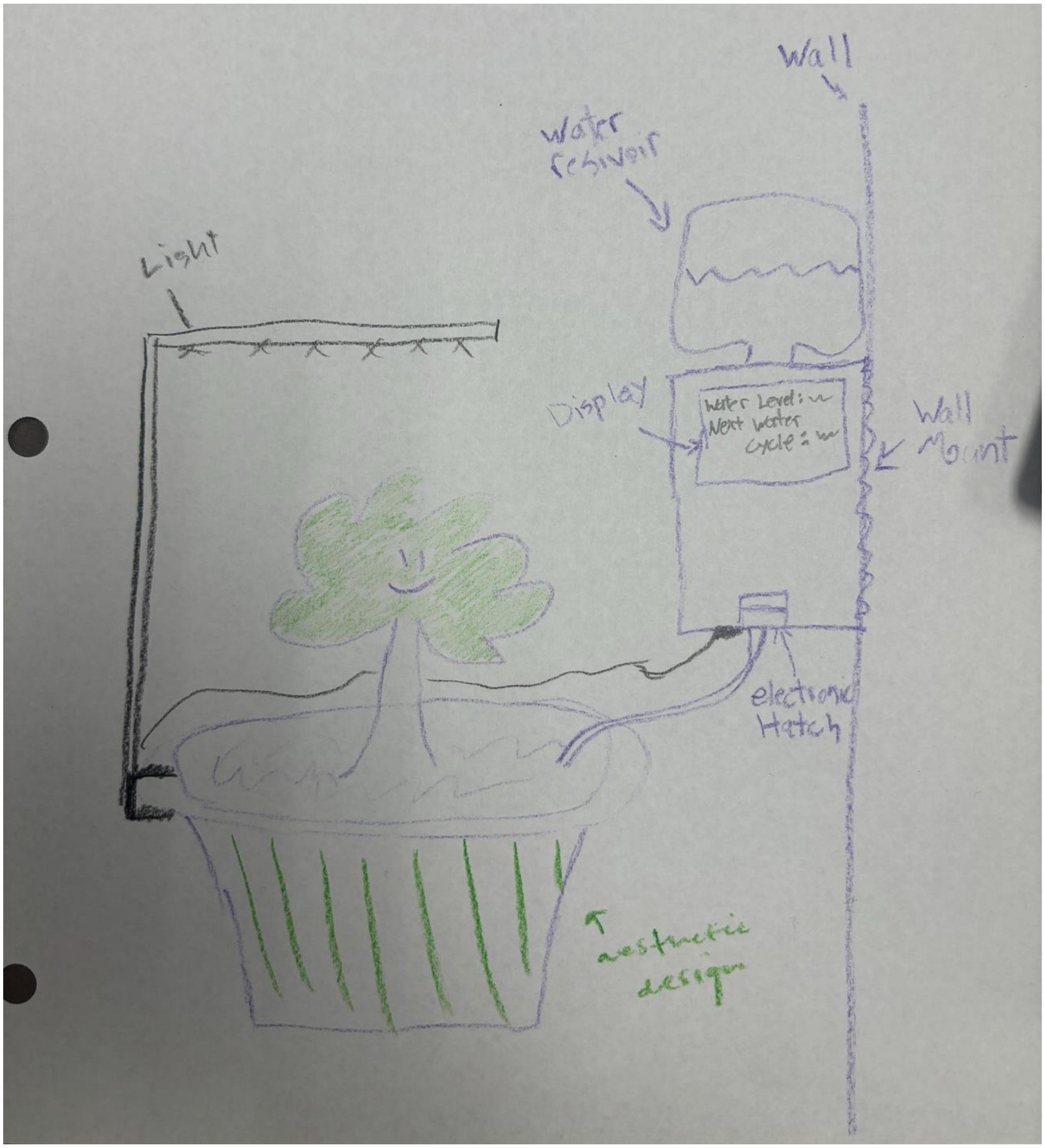


Figure 4 Product Concept Design D

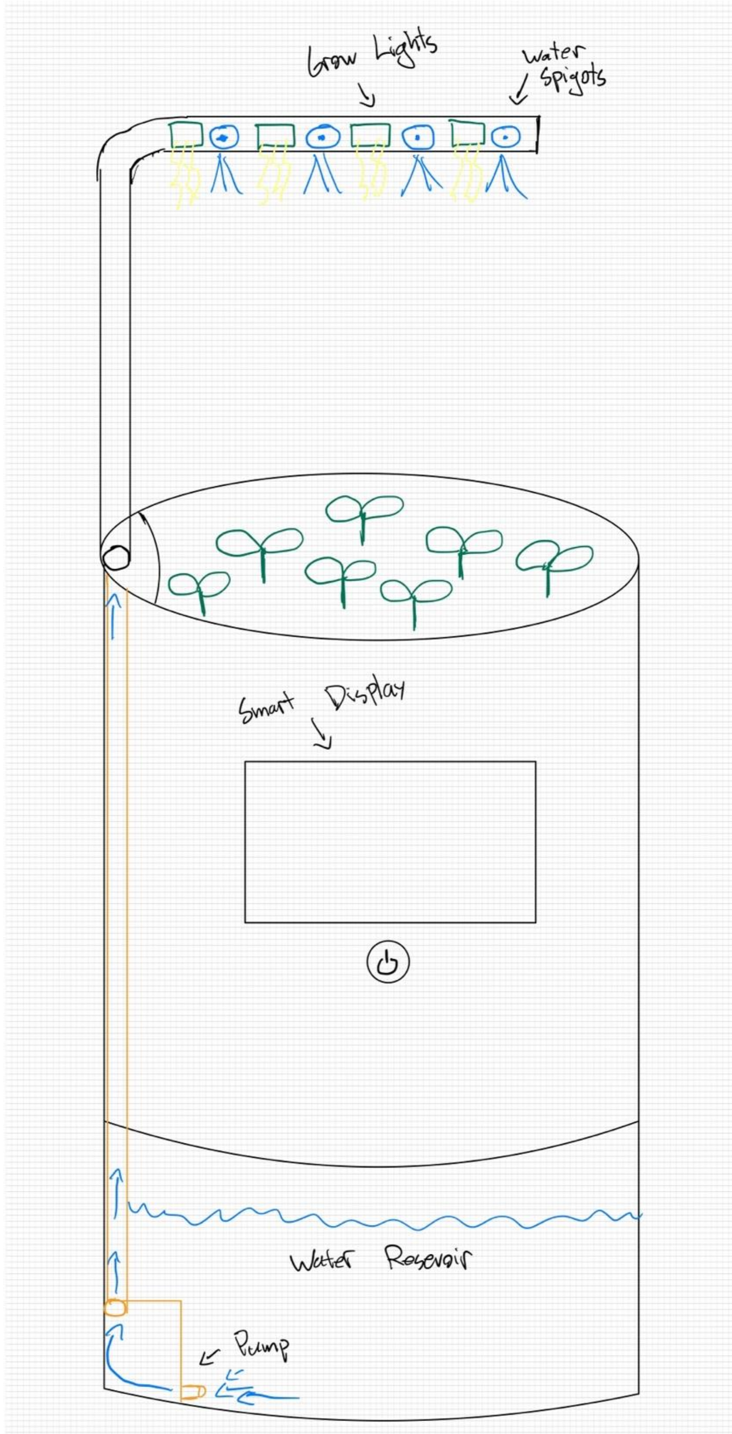


Figure 5. Final Product Concept Design

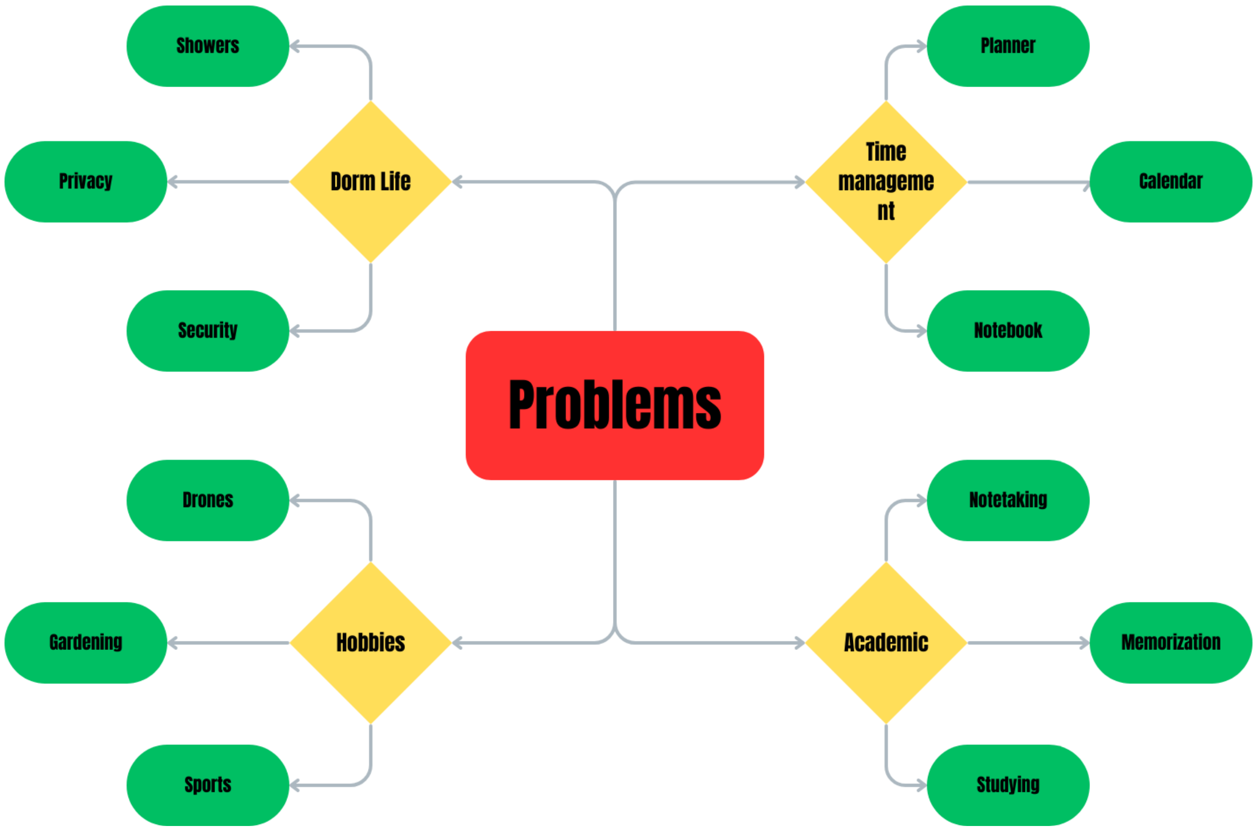


Figure 6. Concept Map

Appendix B. Research Methodologies

Interview	
Q: Can you tell me a little bit about yourself (age, ethnicity, gender, education, socio-economic status, ability, household make-up, etc.)?	• Age 29 • Caucasian • PHD at Harvard • One-Person Household • Lives in Maine
Q: What do you do for a living?	• Doctor at hospital in Maine
Q: What does your typical day look like?	A typical day looks like getting up at 5:00am in the morning, taking an hour to tend to the garden, and getting ready for work. I get to work by around 8am and stay till around 9:00 pm at night. Get home, relax for about an hour, and get ready for the night.
Q: Can you describe some things that bother or frustrate you when performing your routine tasks?	It is frustrating that I have little to no time to enjoy my hobbies of gardening, cooking, and hiking.

Q: Why is this a significant problem?	This is a significant problem because I want to be able to do something fun, but my busy, time-demanding schedule does not allow for it. Though I get enjoyment out of doing it.
Q: What are you currently doing to alleviate this problem?	Currently I am trying to carve out the little time that I have when I am home to engage with some of my hobbies.
Q: What do you like about how you currently handle this problem?	I like that I am currently keeping my solution simple by taking what free time I have to engage with those hobbies.
Q: What is not working about how you currently handle this problem?	I do not like that it takes my limited amount of free time out of my day and how I cannot really see any progress being made because I don't have the time needed to succeed in them.

Figure 1. Interview Notes with Questions Asked and Answers.

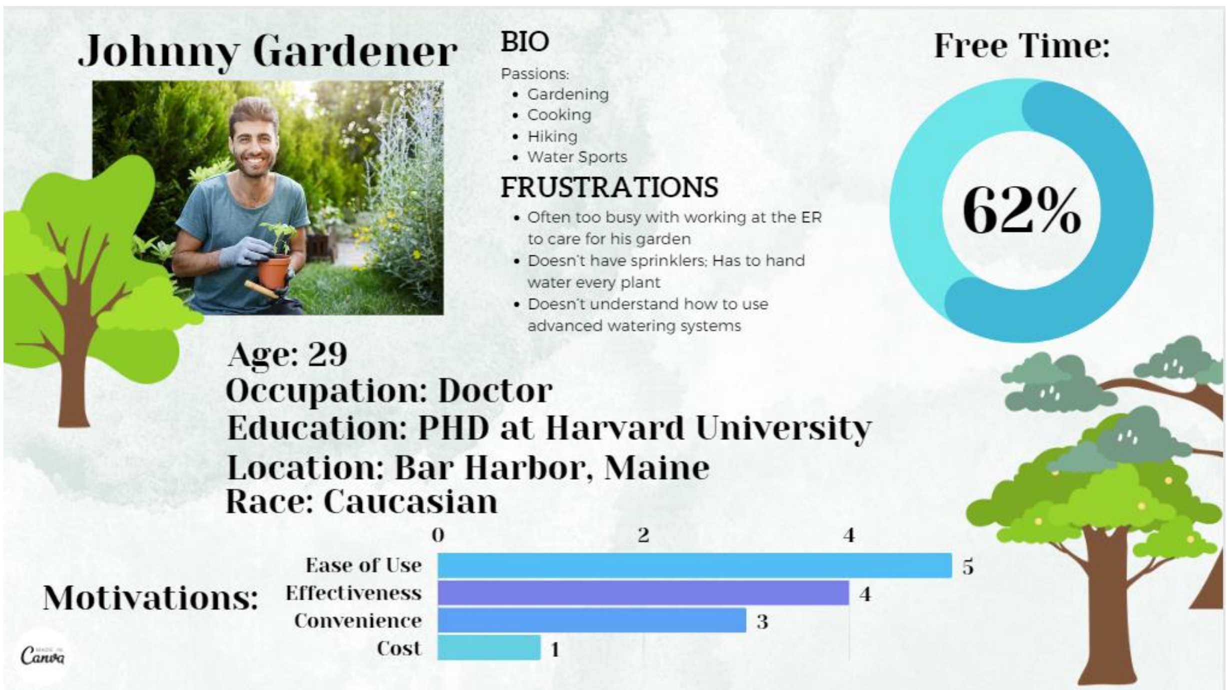


Figure 2. User Persona with Demographics.

	Affordable	High Quality	Low Maintenance	Usability	Effectiveness	Easy Assembly	Versatility w/ plant types	Aesthetics	Durability	Sustainability	Total	Normalized	Predicted
Affordable		0	0	0	0	0	0	0	0	0	0	-	1.9
High Quality	1		0	1	0	1	0	1	1	1	6	3.9	3.7
Low Maintenance	1	1		1	1	1	1	1	0	1	8	5.0	4.5
Usability	1	0	0		1	1	0	1	0	1	5	3.3	3.85
Effectiveness	1	1	0	0		1	1	1	1	1	7	4.4	3.6
Easy Assembly	1	0	0	0	0		0	0	0	0	1	1.0	2.1
Versatility w/ Plant	1	1	0	1	0	1		1	0	1	6	3.9	1.8
Aesthetics	1	0	0	0	0	1	0		0	1	3	2.1	1.5
Durability	1	0	1	1	0	1	1	1		1	7	4.4	3.4
Sustainability	1	0	0	0	0	1	0	0	0		2	1.6	0.5

Figure 3. Pairwise Comparison Chart with User Needs, Total, Predicted, and Normalized Amounts.

User Need	Automatic Drip Irrigation System	Self-Watering Stakes	Rainpoint Automatic Watering System	LetPot System 2.0	Gardyn Home Kit 3.0
Low maintenance	Pass	Pass	Pass	Pass	Pass
Effective	Pass	Fail	Pass	Pass	Pass
Durable	Fail	Fail	Fail	Pass	Pass
High Quality	Fail	Fail	Fail	Pass	Pass
Versatile	Fail	Fail	Fail	Fail	Fail
Affordable	Pass	Pass	Fail	Fail	Fail
Aesthetic	Fail	Fail	Fail	Pass	Pass

Figure 4. Current alternatives mapped against user needs.

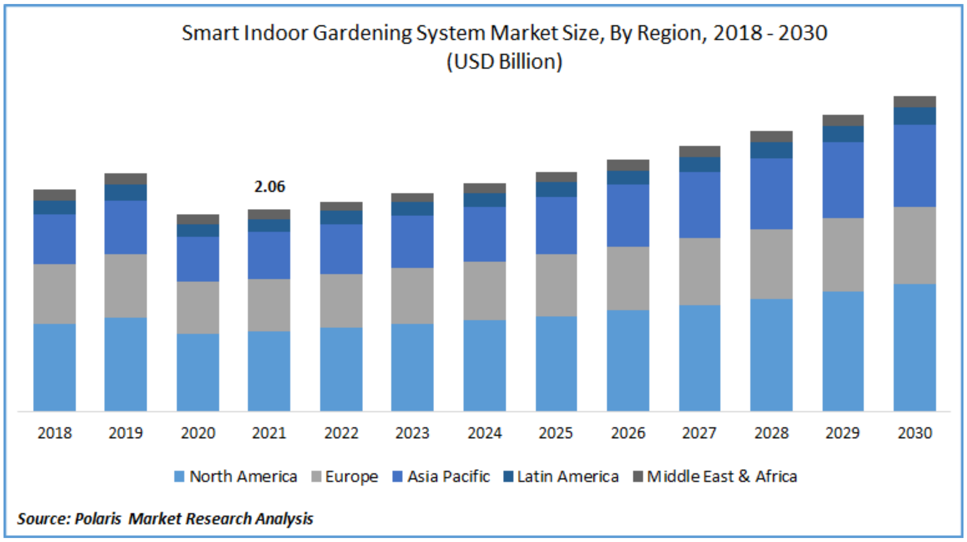


Figure 5. Smart Indoor Gardening System Market Size, By Region, 2018-2030 (USD Billion) by Polaris Market Research Analysis. Retrieved from https://www.polarismarketresearch.com/industry-analysis/smart-indoor-gardening-system-market.

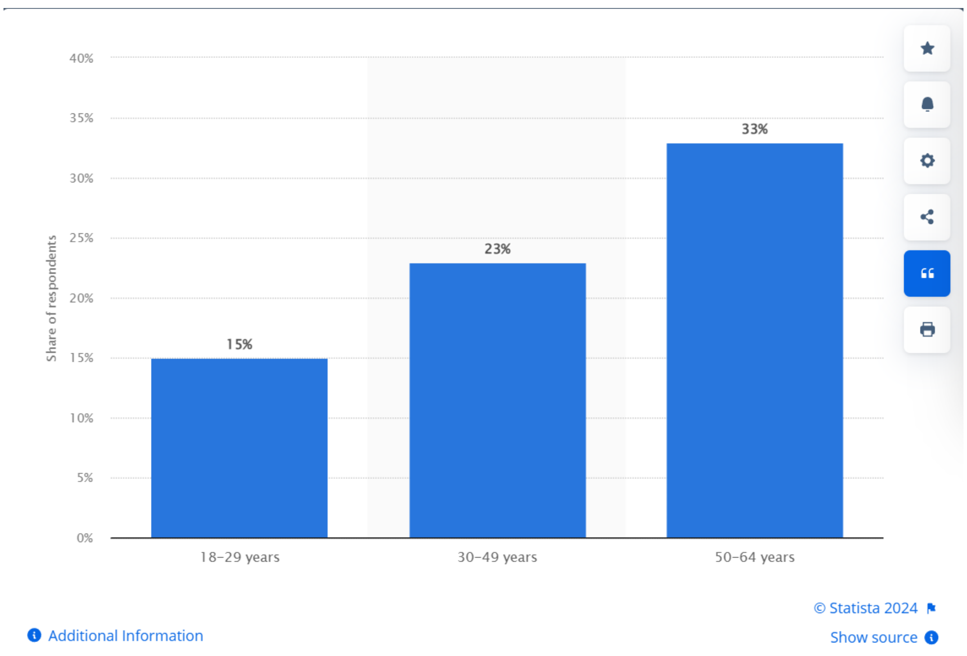


Figure 6. Share of Americans who are interested in gardening and plants as of September 2023, by age by Alexander Kunst. Retrieved from https://www.statista.com/forecasts/227419/number-of-gardeners-usa.

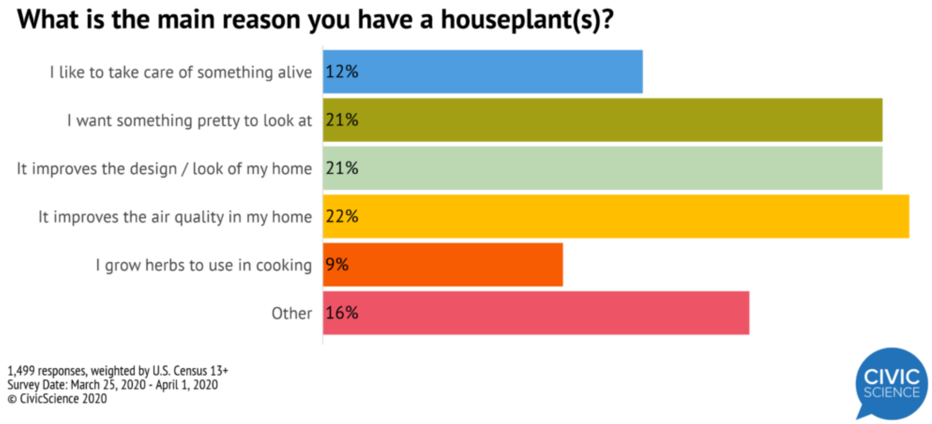
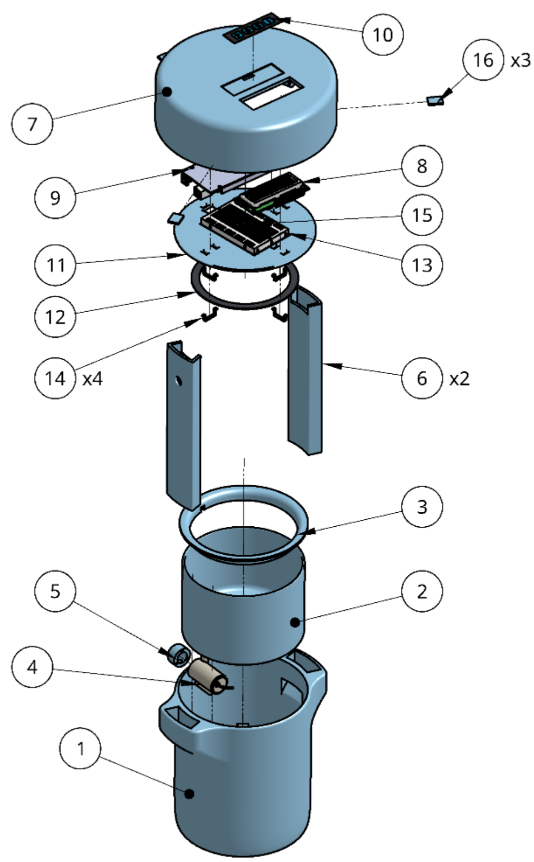


Figure 7. Motivations for keeping houseplants by Luke Revitsky. Retrieved from https://civicscience.com/gen-z-houseplant-ownership-stems-from-the-desire-to-care-for-something-alive/

		Reference		Concept 1 (Matt)		Concept 2 (Julia)	
User Needs	Weight (1-5)	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
High Quality	4	4	16	4	16	4	16
Low Maintenance	5	4	20	5	25	5	25
Effectiveness	4	4	16	5	20	5	20
Versatility w/ Plant	4	3	12	5	20	3	12
Aesthetics	2	4	8	4	8	4	8
Durability	4	4	16	4	16	4	16
TOTAL			88		105		97

Figure 8. Pugh Scoring Matrix

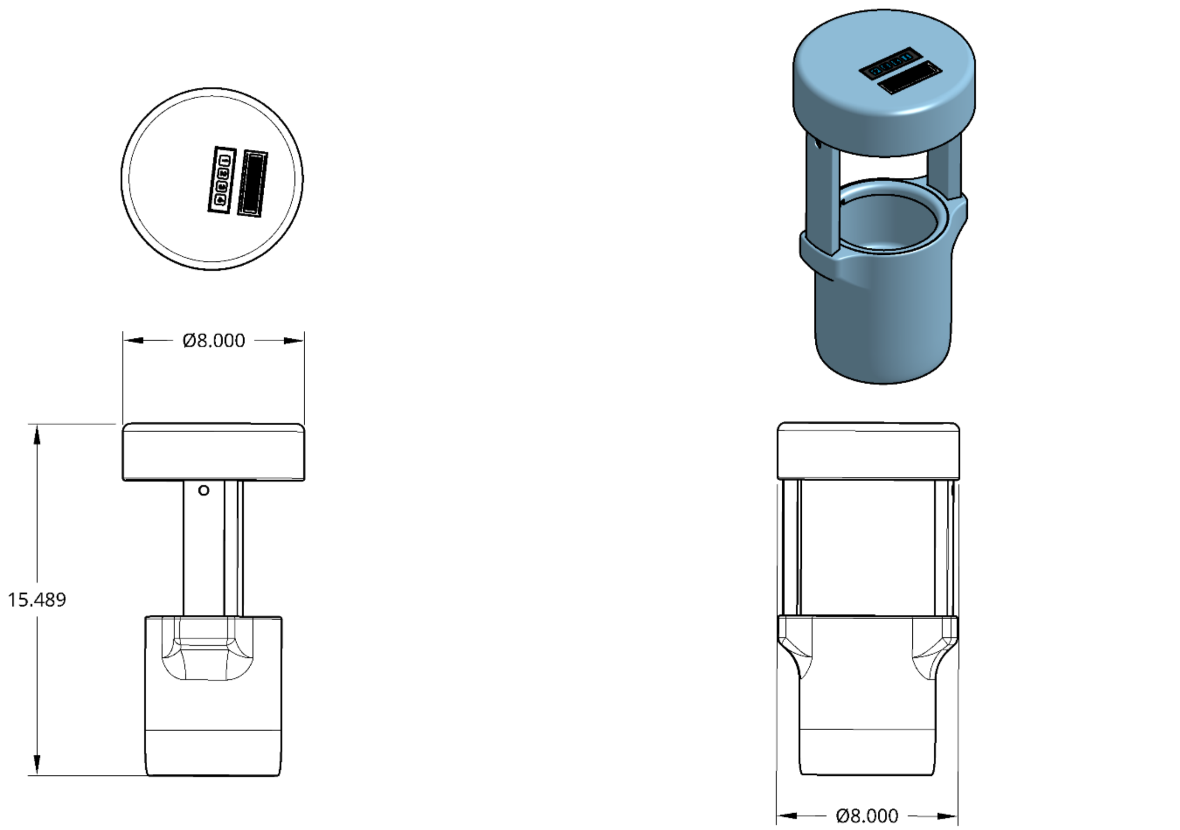
Appendix C. Prototype Working Drawing Packet



Item	Name	Quantity
1	Outer Shell v2	1
2	Upper Half Insert	1
3	Pot Rim	1
4	Mini Pump	1
5	Pump Adapter	1
6	Final Supporting Arm	2
7	Top Cover	1
8	1602 LCD Display	1
9	Arduino	1
10	1 X 4 Key Pad	1
11	Top Cover Bottom	1
12	LED Ring	1
13	Mini Bread Board	1
14	C-Clip	4
15	Motor Driver	1
16	Tab	3

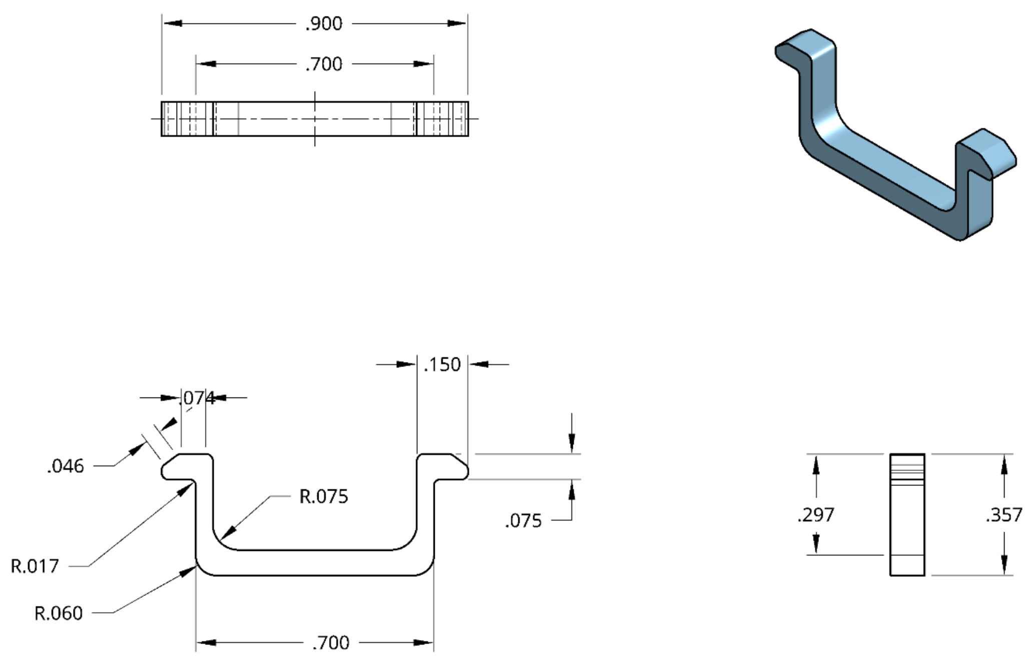
The Ohio State University First Year Engineering	Dwg. Title: Exploded Planter Assembley	Scale: 1:5
	Drawn By: Team N	Units: IPS

Figure 1. Exploded Planter Assembly Drawing with BOM and Balloons.



The Ohio State University First Year Engineering	Dwg. Title: Complete Planter Assembley	Scale: 1:5
	Drawn By: Team N	Units: IPS

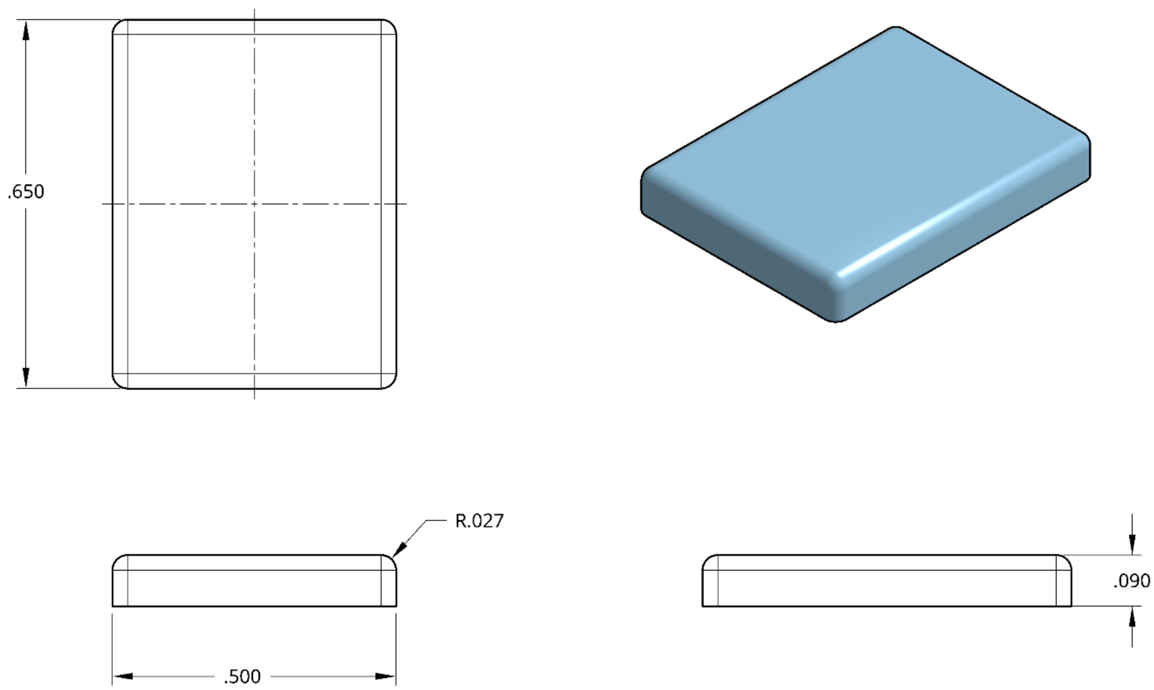
Figure 2. Complete Planter Assembly Drawing with Dimensions.



Note: All Unmarked Fillets are 0.02in

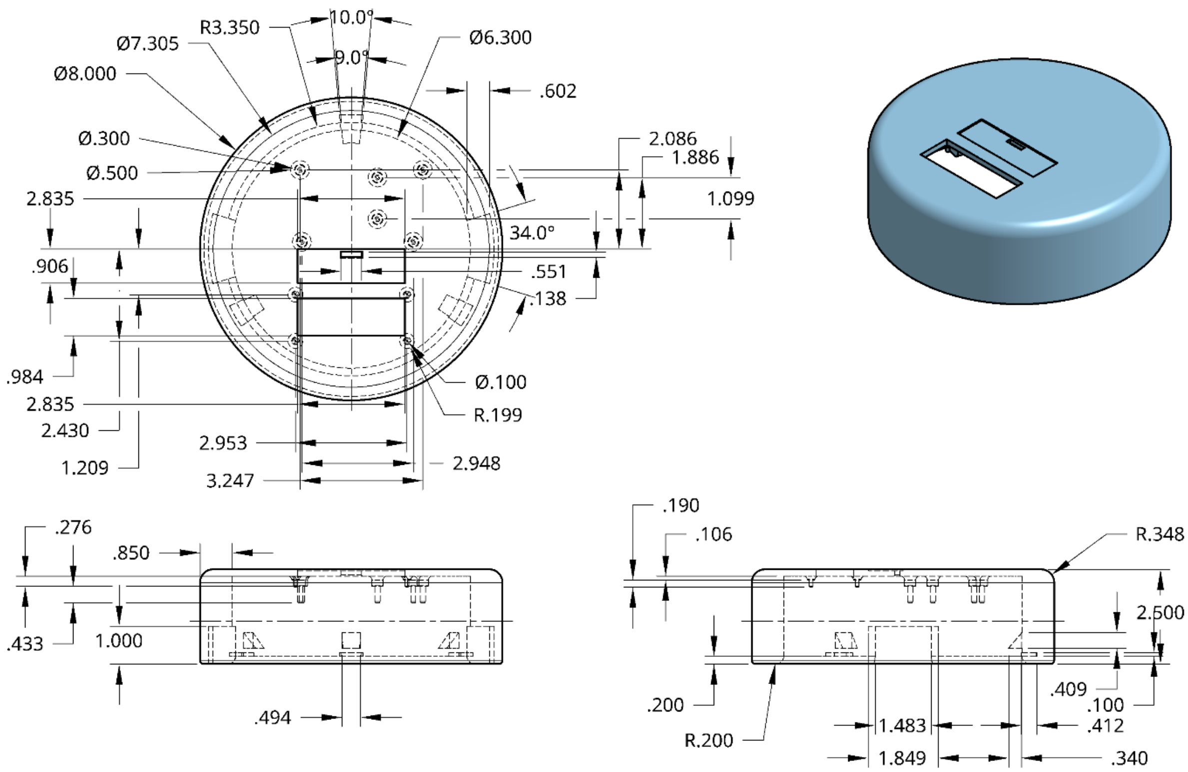
The Ohio State University First Year Engineering	Dwg. Title: C-Clip	Scale: 3:1
	Drawn By: Team N	Units: IPS

Figure 3. C-Clip Drawing with Dimensions.



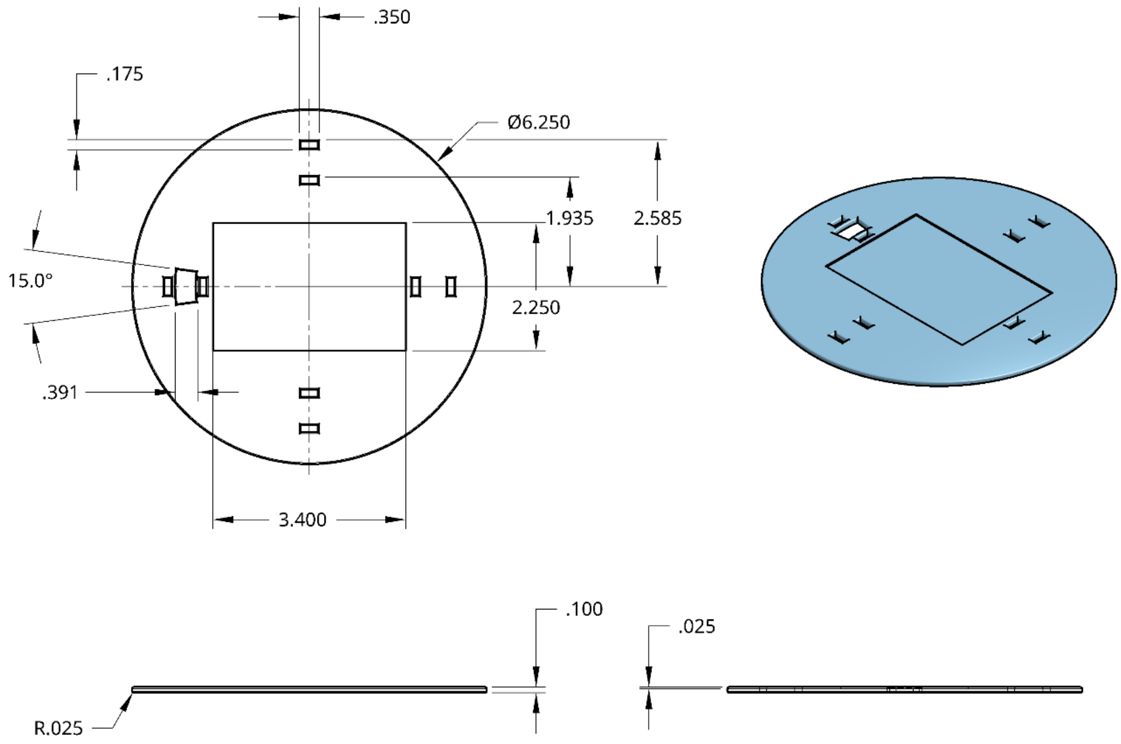
The Ohio State University First Year Engineering	Dwg. Title: Tabs	Scale: 5:1
	Drawn By: Team N	Units: IPS

Figure 4. Tab Drawing with Dimensions.



The Ohio State University First Year Engineering	Dwg. Title: Top Cover	Scale: 1:3
	Drawn By: Team N	Units: IPS

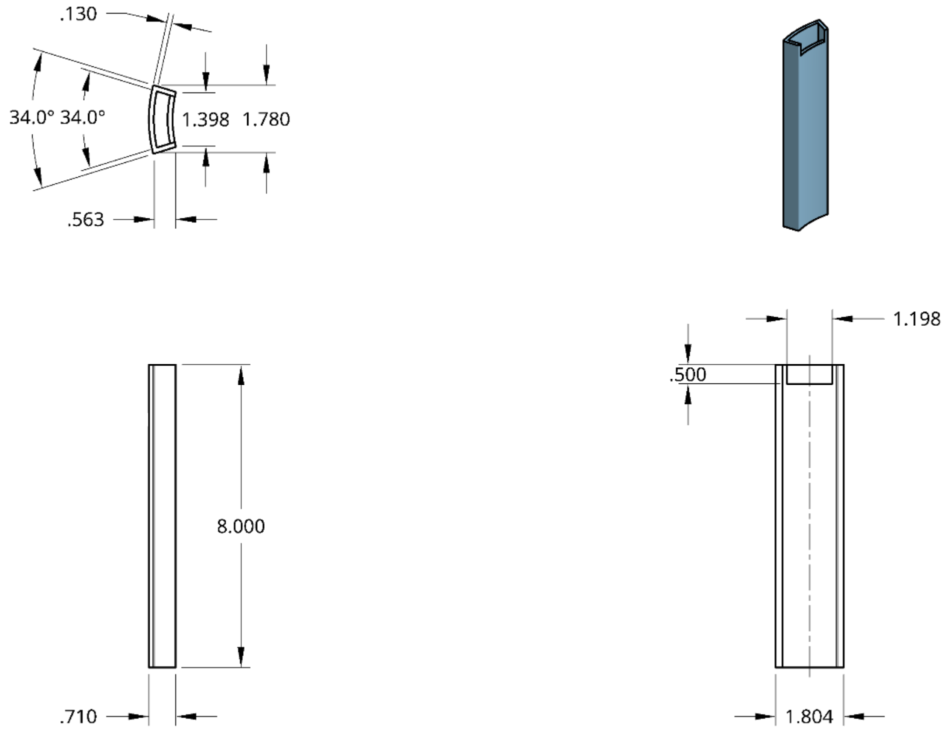
Figure 5. Top Cover Drawing with Dimensions.



Note: All unmarked Fillets are 0.25in

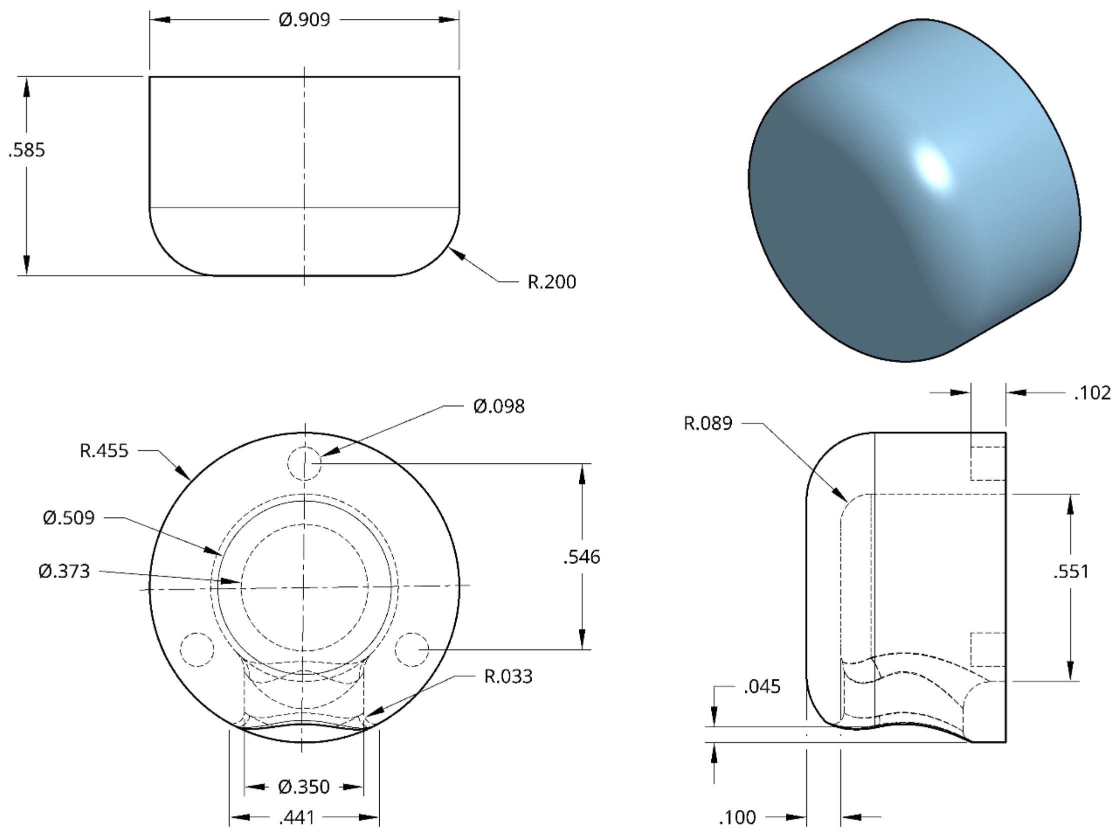
The Ohio State University First Year Engineering	Dwg. Title: Top Cover Bottom	Scale: 1:2
	Drawn By: Team N	Units: IPS

Figure 6. Top Cover Button Drawing with Dimensions.



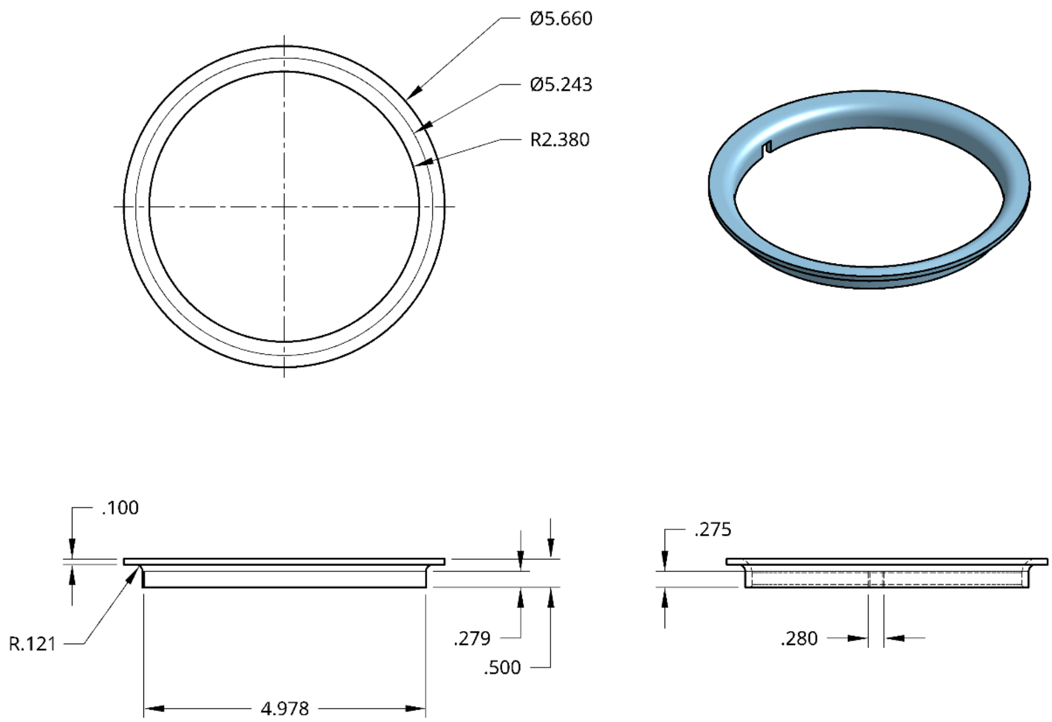
The Ohio State University First Year Engineering	Dwg. Title: Supporting Arm	Scale: 1:3
	Drawn By: Team N	Units: IPS

Figure 7. Supporting Arm Drawing with Dimensions.



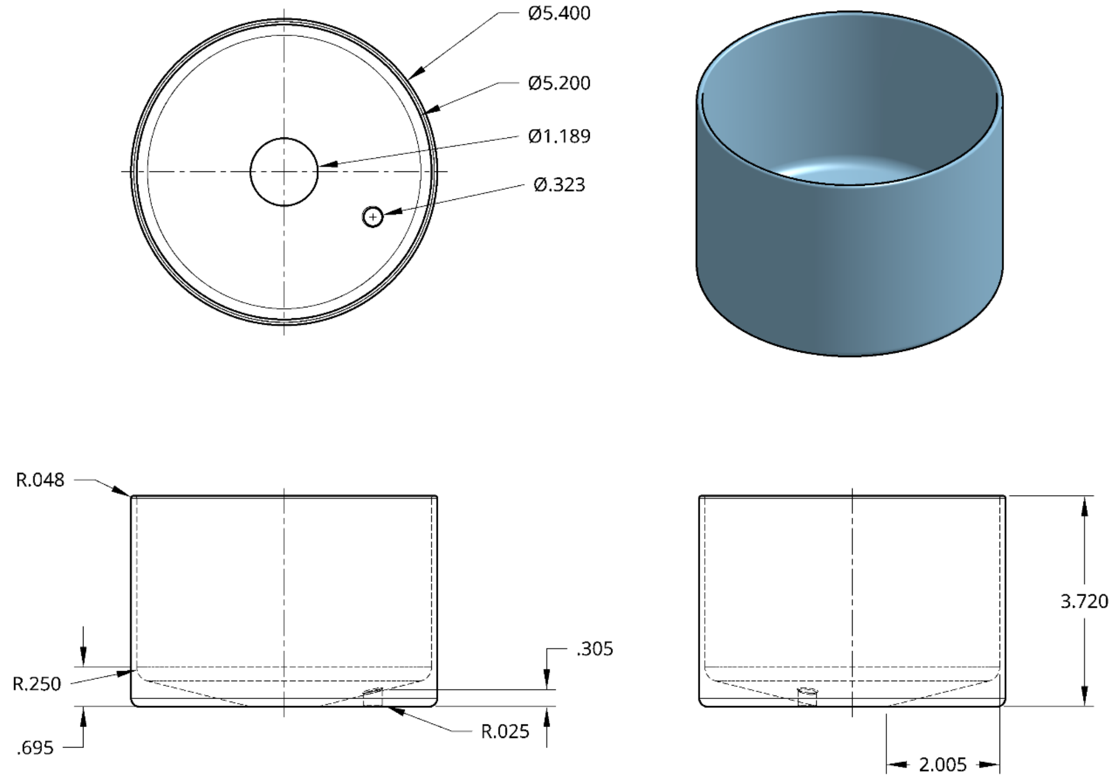
The Ohio State University First Year Engineering	Dwg. Title: Pump Adapter	Scale: 3:1
	Drawn By: Team N	Units: IPS

Figure 8. Pump Adapter Drawing with Dimensions.



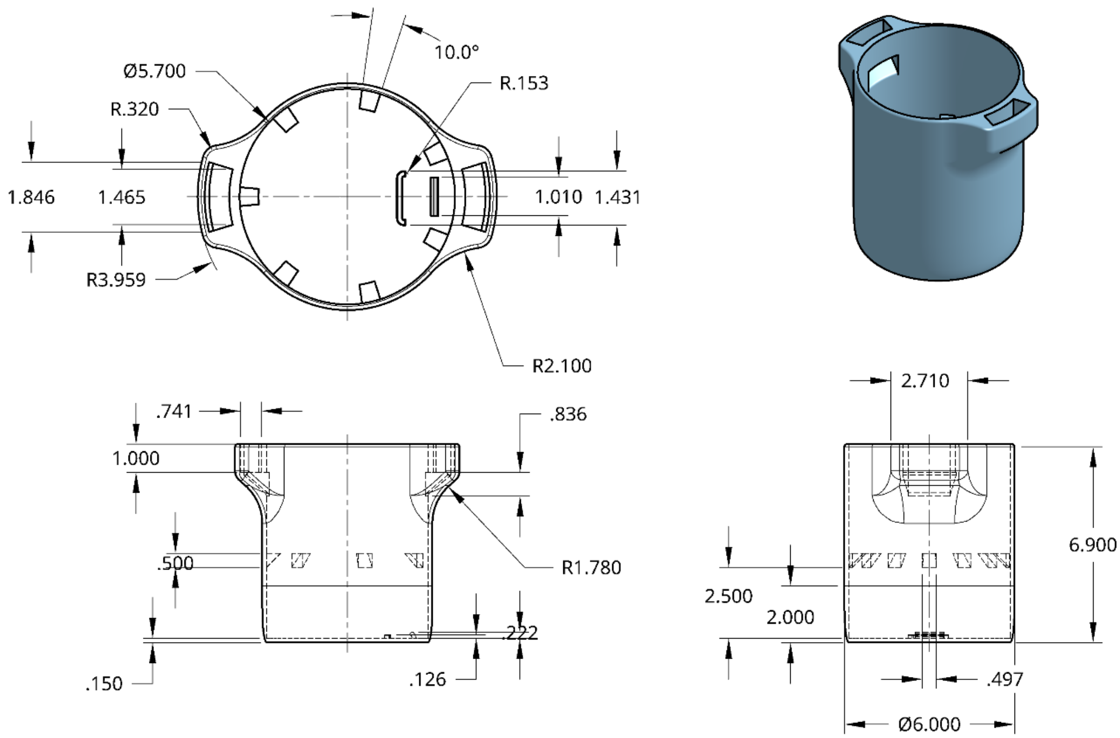
The Ohio State University First Year Engineering	Dwg. Title: Pot Rim	Scale: 1:2
	Drawn By: Team N	Units: IPS

Figure 9. Pot Rim Drawing with Dimensions.



The Ohio State University First Year Engineering	Dwg. Title: Upper Half Insert	Scale: 1:2
	Drawn By: Team N	Units: IPS

Figure 10. Upper Half Insert Drawing with Dimensions.



The Ohio State University First Year Engineering	Dwg. Title: Outer Shell	Scale: 1:3
	Drawn By: Team N	Units: IPS

Figure 11. Outer Shell Drawing with Dimensions.

Appendix D. Software Code (if applicable, remove if not used)

```
//Keypad
#define key1 16 //define keypad pins
#define key2 17
#define key3 14
#define key4 15
//LCD
#include <LiquidCrystal.h>
const int rs = 13, en = 12, d11 = 11, d10 = 10, d9 = 9, d8 = 8; //define lcd pins
LiquidCrystal lcd(rs, en, d11, d10, d9, d8); //instantiate lcd
//SHT
#include <Arduino.h>
#include <Wire.h>
#include "Adafruit_SHT31.h"
Adafruit_SHT31 sht31 = Adafruit_SHT31();
//Neopixel
#include <Adafruit_NeoPixel.h>
#define PIN 6
#define NUMPIXELS 45
Adafruit_NeoPixel pixels(NUMPIXELS, PIN, NEO_GRB + NEO_KHZ800);
//Pump
#define out_STBY 3
#define out_A_PWM 7
#define out_A_IN2 4
#define out_A_IN1 5
#define motor_A 0
//Variables
bool power = false;
bool enableHeater = false;
uint8_t loopCnt = 0;
int t = 0;
int h = 0;
bool mode1 = false;
bool mode2 = false;
bool mode3 = false;


void setup() {
//Debug
Serial.begin(9600);
//Keypad
pinMode(key1, INPUT_PULLUP);// set pin as input
pinMode(key2, INPUT_PULLUP);// set pin as input
pinMode(key3, INPUT_PULLUP);// set pin as input
pinMode(key4, INPUT_PULLUP);// set pin as input
```

```
//LCD
lcd.begin(16, 2);// Set up the LCD's number of columns and rows
lcd.print("Power off");
//Neopixel
pixels.begin();
//SHT
Serial.println("SHT31 test");
if (! sht31.begin(0x44)) { // Set to 0x45 for alternate i2c addr
Serial.println("Couldn't find SHT31");
while (1) delay(1);
}
Serial.print("Heater Enabled State: ");
if (sht31.isHeaterEnabled())
Serial.println("ENABLED");
else
Serial.println("DISABLED");
//Motor
pinMode(out_STBY, OUTPUT);
pinMode(out_A_PWM, OUTPUT);
pinMode(out_A_IN1, OUTPUT);
pinMode(out_A_IN2, OUTPUT);
motor_standby(true);//motor off
motor_speed(100); // Set speed for motor A
}

void loop() {
lcd.setCursor(0, 0);
//Check for key presses
int key1S = digitalRead(key1);// read if key1 is pressed
int key2S = digitalRead(key2);// read if key2 is pressed
int key3S = digitalRead(key3);// read if key3 is pressed
int key4S = digitalRead(key4);// read if key4 is pressed
if(power == false){ //Loop to wait for power on
if(!key1S){
power = true;
lcd.clear();
lcd.print("Power on");
delay(1500);
}
}else if(power == true){ //Main running loop
//Mode checks
if(!key2S || mode1 == true){
if(mode1 == false){
lightOn();
}
cycle(1, 40);
mode2 = false;
mode3 = false;
```

```
mode1 = true;
}
if(!key3S || mode2 == true){
if(mode2 == false){
lightOn();
}
cycle(2, 60);
mode1 = false;
mode3 = false;
mode2 = true;
}
if(!key4S || mode3 == true){
if(mode3 == false){
lightOn();
}
cycle(3, 80);
mode1 = false;
mode2 = false;
mode3 = true;
}
//Humidity
t = sht31.readTemperature();
h = sht31.readHumidity();
lcd.setCursor(0,1);
lcd.print("Temp:"); lcd.print(t);
lcd.setCursor(10,1);
lcd.print("Hum:"); lcd.print(h);
if (loopCnt >= 5) {
enableHeater = !enableHeater;
sht31.heater(enableHeater);
Serial.print("Heater Enabled State: ");
if (sht31.isHeaterEnabled())
Serial.println("ENABLED");
else
Serial.println("DISABLED");
loopCnt = 0;
}
loopCnt++;
//Turn power off
if(!key1S){
power = false;
lcd.clear();
lcd.print("Power off");
motor_standby(true);
pixels.clear();
pixels.show();
delay(1500);
}
```

```
}
delay(10);
}

void cycle(int mode, int humLimit) {
motor_standby(true);
lcd.setCursor(10,0);
lcd.print("Mode ");lcd.print(mode);
if(h < humLimit){
motor_standby(false);
}else{
motor_standby(true);
}
}

void lightOn(){
for(int i=0; i<NUMPIXELS; i+=3) {
pixels.setPixelColor(i, pixels.Color(84, 64, 255));
pixels.setPixelColor(i+1, pixels.Color(255, 0, 0));
pixels.setPixelColor(i+2, pixels.Color(163, 255, 0));
pixels.show();
delay(5);
}
}

void motor_speed(char speed) { // Speed from -100 to 100
byte PWMvalue = map(abs(speed), 0, 100, 50, 255); // Anything below 50 is very weak
if (speed > 0) {
digitalWrite(out_A_IN1, HIGH);
digitalWrite(out_A_IN2, LOW);
} else if (speed < 0) {
digitalWrite(out_A_IN1, LOW);
digitalWrite(out_A_IN2, HIGH);
} else {
digitalWrite(out_A_IN1, LOW);
digitalWrite(out_A_IN2, LOW);
}
analogWrite(out_A_PWM, PWMvalue);
}

void motor_standby(boolean state) { // Low power mode
if (state == true)
digitalWrite(out_STBY, LOW);
else
digitalWrite(out_STBY, HIGH);
}
```

Appendix E. Additional Raw Data

Appendix F. Project Management Schedule and Meeting Minutes

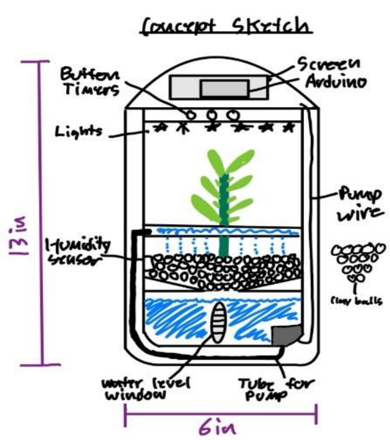
17. Project Schedule

Major Project Deliverables – The team will have several major project deliverables including a functional and properly working to scale prototype. For the prototype to become fully functional, it is imperative the prototype passes the tests outlined in the verification plan. These tests include testing all three watering interval buttons, weighing the product to ensure it is lightweight, measuring water basin's volume, calculating the overall market price of the product to compare the product with similar competing products, and users will find that the product is overall timesaving. After fulfilling these verifications, the team is confident that the product will be fully functional as a final deliverable. The team has also made it a goal to present their product in the Engineering student showcase at the end of the Spring '24 semester. Accomplishing this goal would be representative of a successful design and product as a culmination of the team's hard work this semester.

In the team's project schedule, some of the most important tasks that need to be a priority are assembly, electronics, and code working, as these are the essential main branches of the project. Without these aspects, the prototype would not be complete by the due date and function appropriately. Some bottlenecks that could be encountered along the way are the code and electronics all depending on having the top half assembled before they can be completed, thus the top half being assembled is vital for the project. In addition, tests need to be conducted but are interdependent based on the code and the electronics functioning properly within the system. Delays in any of these areas can push back both final assembly and potentially the transplantation of the plant.

Gantt Chart

Prototype Plan



To bring the Grow Guru product, or the smart hydroponics plant care system, to life, a high-level prototyping plan will be followed and thoroughly designed. This prototype will be high-functioning and all required elements of user interest such as low maintenance and high durability should be met.

The product has many functions and qualities but the amount of free pin locations in the breadboard and Arduino limits the connectivity of these many functions which may have overlapping pins. The main goal is for the device to at least water the plant successfully in accordance with the correct intervals set with each button. So, to prevent the aforementioned factors from limiting the success of the product, these functions will be prioritized.

The plan is to begin with the bottom basin preparation for assembly by mod podging the surfaces to ensure the product remains water leak proof. The metal wire mesh should be added to the bottom of the pot insert. A pump tube, humidity sensor, and water pump are needed and will be installed next to cover the first priority. The board and wiring will be taken care of as well and afterwards tests will begin.

It is anticipated that the resources from the preliminary R&D needed to build the prototype would include the 4 by 1 Membrane pad for the buttons to hold code for different watering intervals, the Adafruit Soil Sensor to read the soil humidity and temperature, and LCD Screen and more. Putting these together would bring maximum efficiency and effectiveness out of the product design and would result in a functional high-level prototype.

18. Prototyping Workday 1 Meeting Minutes

3/1/2024 2:55-4:00 Smith LAB

Members: Matthew Allen, Navneet Kaur, Joseph Davancaze, & Julia Kucaric

Objective statement: This meeting's purpose is to begin initial construction of the protype, including waterproofing the basin with Mod Podge and putting the mesh screen on the bottom of the pot. As well as testing the components to ensure they work.

Completed tasks:

- Waterproof Pot & Basin (Apply 3 coats of Mod Podge): Matthew & Navneet
- Cut & Affix Mesh to pot (Cut mesh to size and glue to pot): Julia
- Test Components with Arduino IDE (Test functionality of components): Joseph

Tasks to be completed:

- Attach Arduino, Bread board, Screen, and Ring Light: Matthew & Joseph
- Transfer Basil Sprouts to Temporary pots: Navneet & Julia

Project timeline: Gantt Chart- 6.67% Completed

Decisions:

- How many coats to apply to waterproof components
- Add a water retention test (See if more coats needed)

19. Prototyping Workday 2 Meeting Minutes

3/4/2024 3:00-5:00 Smith LAB

Members: Matthew Allen, Navneet Kaur, Joseph Davancaze, & Julia Kucaric

Objective statement: This meeting's purpose is to attach the necessary components such as the pump, place pot, add clay pebbles to the pot, assemble the top half of the prototype, and attach the Arduino, breadboard, screen, and ring light. The rim was also touched up a bit and made smoother for safety and aesthetics.

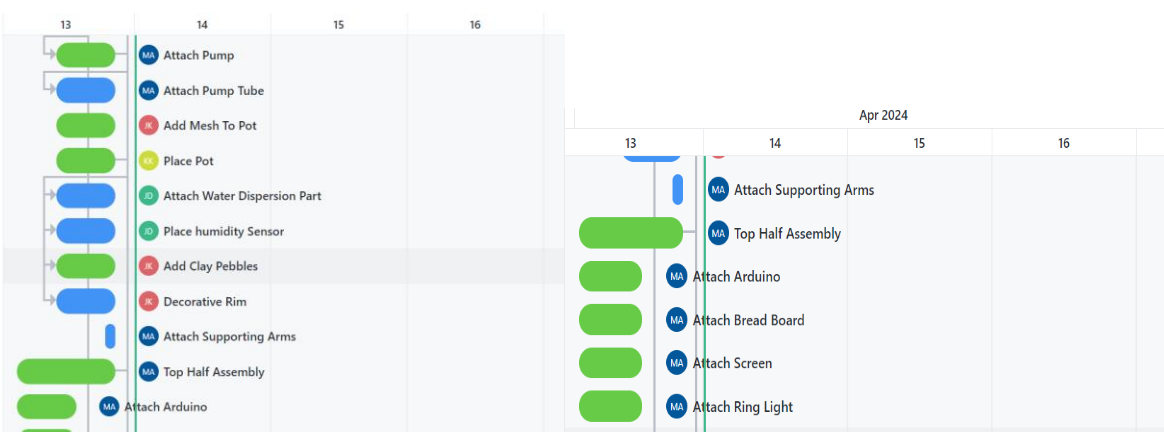
Completed tasks:

- Attached water pump to base of prototype: Matthew Allen
- Soldered wires to ring light: Navneet Kaur & Matthew Allen
- Add clay pebbles to pot: Julia Kucaric
- Attached breadboard to pegs: Joseph Davancaze
- Attached Arduino to pegs: Joseph Davancaze
- Attached keypad: Navneet Kaur
- Touched up rim of pot to ensure safety and smoothness: Julia Kucaric
- Attached ring light to ceiling of design: Navneet Kaur

Tasks to be completed:

- Attach Water dispersion part: Joseph Davancaze
- Place Humidity sensor: Joseph Davancaze
- Attach supporting arms: Matthew Allen
- Attach the water pump tube: Navneet Kaur & Julia Kucaric

Project timeline: Gantt Chart- 23.4% Completed



Decisions:

How many lightweight large pebbles vs. Small compact heavy pebbles to add for the health of the plant?

Original 3D printed pieces to lock ring light in place did not fit properly. Should the team reprint? Ultimately decided not to and used found materials (paper clips) to lock it in place due to malleability, durability, and aesthetic green color.

20. Prototyping Workday 3 Meeting Minutes

4/15/2024 3:00-6:00 Smith LAB

Members: Matthew Allen, Navneet Kaur, Joseph Davancaze, & Julia Kucaric

Objective statement: This meeting's purpose is to test all necessary components, find any bugs within the code, and adjust as needed. Tests conducted include weight with all elements combined, water basin capacity measurement, and keypad tests. The water tube is also to be sealed off at the end and has small incisions along the sides to allow water to disperse throughout the soil or clay pebbles.

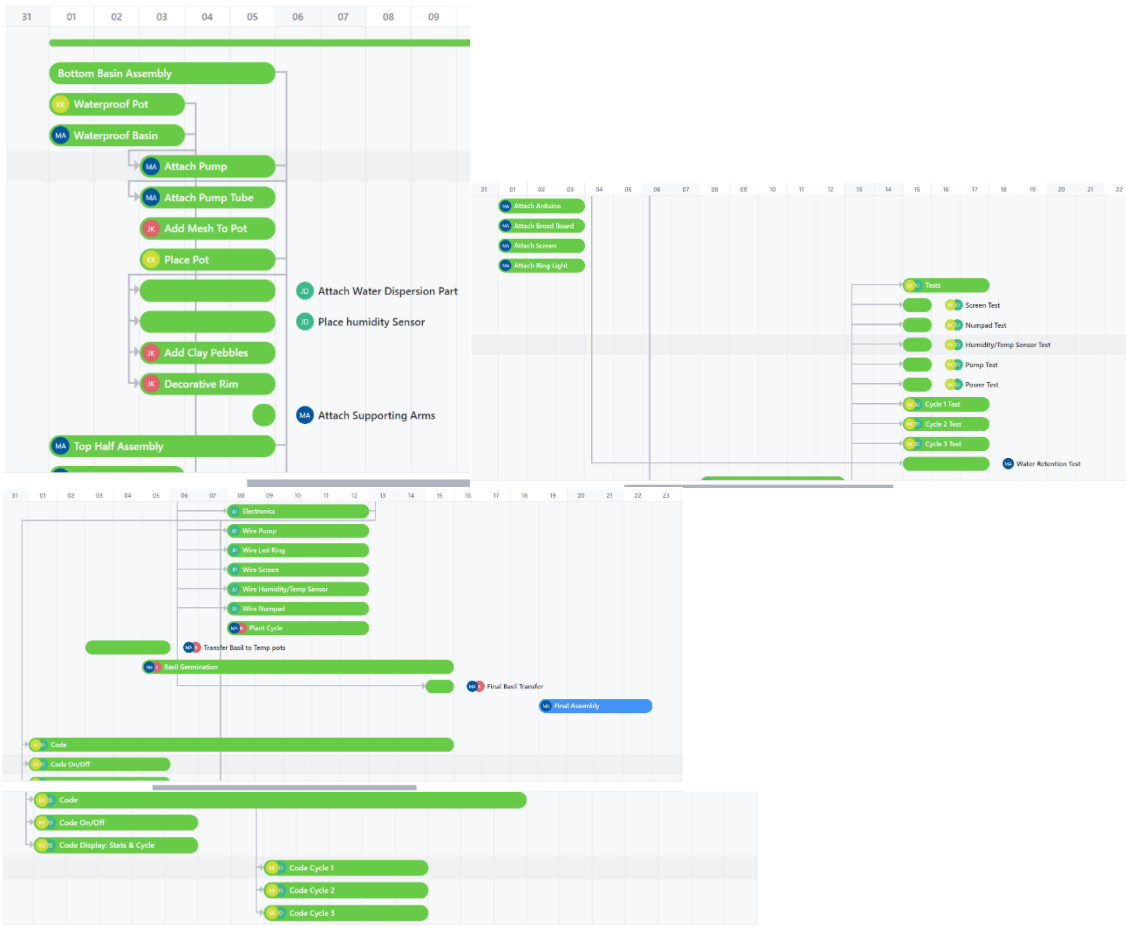
Completed tasks:

- Screen Test: Joseph
- Numpad Test: Joseph
- Humidity/Temp Sensor Test: Matthew & Joseph
- Water Basin Capacity Test: Navneet, Julia, Joseph
- Pump Test: Matthew, Navneet, Joseph
- Power Test: Joseph
- Seal water tube: Navneet, Matthew, Joseph
- Cycle 1 Test: All members
- Cycle 2 Test: All members
- Cycle 3 Test: All members
- Water Retention Test: Julia
- Create water tube dispersion incisions: Navneet & Joseph
- Pot plants into Grow Guru: All members

Tasks to be completed:

- Double check everything to ensure device is working: All members
- Final Assembly: All members

Project timeline: Gantt Chart- 97.8% Completed



Decisions:

- It was decided to seal off the tube end and create dispersion using incisions based on user feedback. What kind of incisions should be made to allow the water tube to disperse water properly? Poke holes? Make dash mark slits? Slit the entire side? These were influenced by the elasticity of the tube because a small incision or holes would close back up and not allow water to flow through. To fix this, it was decided to use plus style incisions and cut off a small corner of one of the resulting triangles.
- How many incisions to make along the tube? Decided to evenly split them apart by around an inch or two to create a more balanced design to compete with mass manufacturers.

21. Prototyping Workday 4 Meeting Minutes

4/17/2024 4:00-5:30 Hitchcock 308

Members: Matthew Allen, Navneet Kaur, Joseph Davancaze, & Julia Kucaric

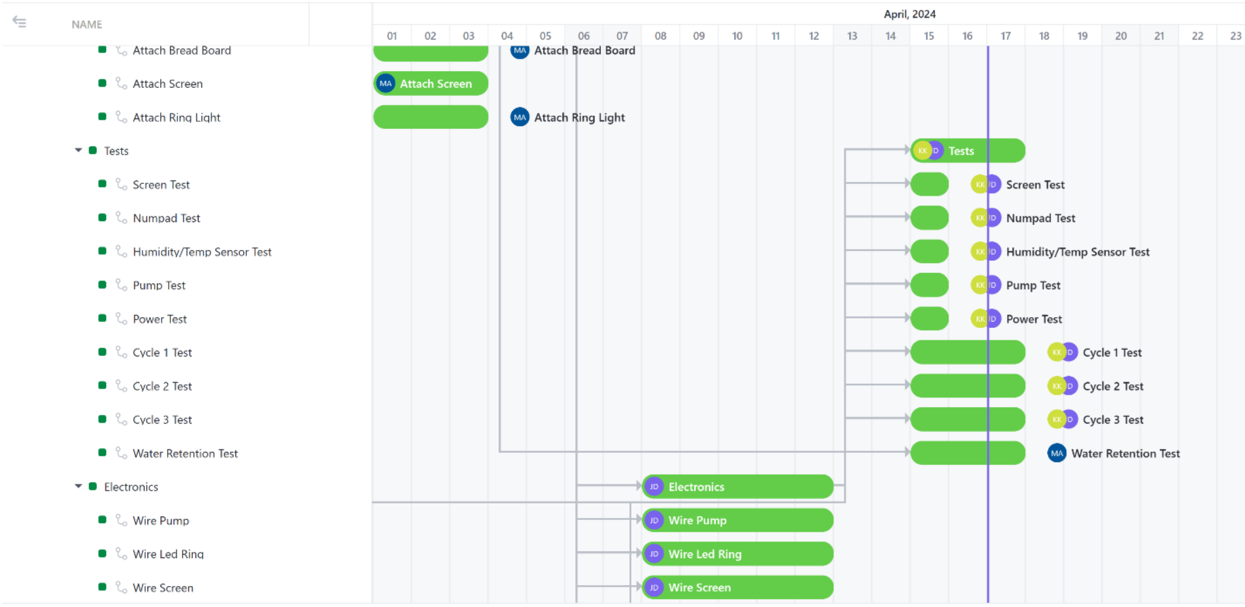
Objective statement: This meeting's purpose is to fix the power source so that the batteries can correctly power the screen and to debug code to make sure the keypad works, and the light stays on while the modes are changing from button to button.

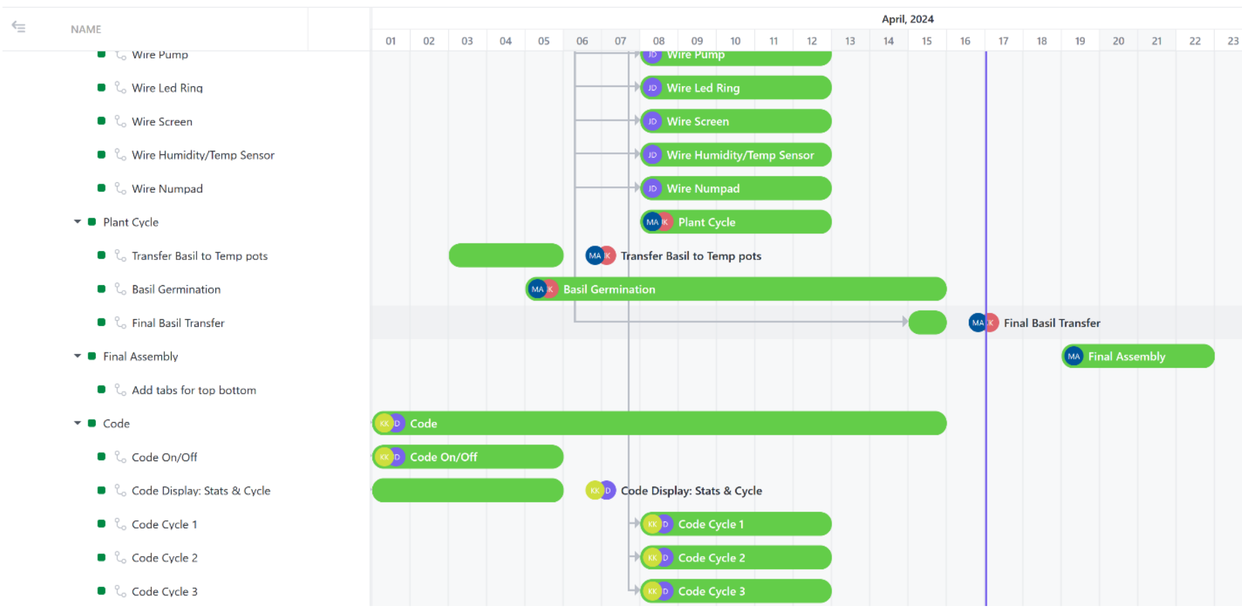
Completed tasks:

- Attached water dispersion part: Joseph Davancaze
- Placed humidity sensor: Navneet Kaur
- Attached support arms: Matthew Allen
- Attached the water pump tube: Julia Kucaric
- Debugged code: Joseph Davancaze
- Fixed power source: Matthew Allen

Tasks to be completed: N/A

Project timeline: Gantt Chart- 100% Completed





Decisions:

- It was decided that the issue with the power was that there was not enough current being pulled with the existing wire and said wire should be replaced to fix the power issue. The team is currently investigating potential options for power sources and deciding which will work best for the final product.

Appendix G. Team Working Agreement

Team Working Agreement
Term Spring 2024
1/18/2024.
Revised: 2/28/2024.

1. Team Information

Course Section # 8135
Team Designation: N
Instructor and GTA: Assad Iqbal, Nicholas Yeoh
Team Name (Optional)

Contact Information:

Name	Email Address	Phone Number
Joseph Davancaze	Davancaze.1@osu.edu	(650) 448-9970
Matthew Allen	Allen.2906@osu.edu	(512) 609-9079
Julia Kucaric	Kucaric.4@osu.edu	(571) 494-7127
Navneet Kaur	Kaur.361@ose.edu	(740) 505-3478

2. Team Values & Goal

What are the team's top 5 values?

- Teamwork
- Respect
- Equality
- Humor
- Loyalty/Honesty

What are the team's expectations of quality level? Top goals? Minimum acceptable goals? Include at least 1 goal regarding psychological safety, belonging, and inclusion.

- Everything we submit as a team should be our top level of performance and effort.
- Include everyone's ideas and be accepting.
- Listen to everyone and do not talk over them.
- Ensure that our work is a culmination of every team member's ideas and participation

3. Communication and Meetings

What are your team's preferred method(s) of contact and expected response time(s)?

- Team group chat in messages
- Response or a rection should be within 24 hours of the message sent if not pertaining to an assignment, if the message is regarding an assignment with an approaching due date, responses are expected in a timely manner (quickly)

How often do you plan on meeting to achieve your goals? (Do you anticipate this changing throughout the semester?)

- Once or twice a week depending on what assignments are due for the week and the complexity of the assignments

Primary and Secondary Meeting Day/Time/Location
- Meeting at 18th Avenue Library Basement Fridays at 3:00pm
- Tuesdays 18th Avenue Library at 8pm

Individual(s) in charge of agendas, reminders, minutes
- Everyone shares the responsibility of adding "Clickup" tasks for the team equally

4. General Expectations and Group Norms

How are team members expected to behave? What are the group norms?
- Kind
- Understanding
- Respectful
- Willing to Cooperate and work together
- Be responsible for one's tasks and timely with completing them
- Communicate well with each other
- Ask each other for input and ideas to create a more accepting group culture

What are acceptable/unacceptable types of interaction?
- Rudeness is unacceptable
- Not communicating is unacceptable
- Communicating is acceptable
- It is unacceptable to talk over each other and not allow for others to express themselves or their ideas
- It is acceptable to reach out for help when needed
- It is acceptable to trade tasks and negotiate them amongst group member even after members have been assigned their tasks

What are the team member's expectations regarding attendance?
- Come to meetings unless certain emergencies or circumstances prohibit you.
- Same goes for in-class attendance as not attending may limit the knowledge and abilities of the person if absence is prolonged

How are team members expected to behave during lab/class periods?
- Good listening
- Contribute
- Be involved in the learning environment, ask questions, and participate in activities or answering questions
- Be respectful to each other
- Apply feedback from teaching staff or group members to improve quality of self and in class participation

What are team members meant to do between classes? Lab/class preparation?
- Work on assigned tasks
- Attend any meetings that were scheduled at those times
- Revise and edit documents before submission and compare to rubric to ensure quality

How are team members meant to ensure the team stays on track?
- Check in on others
- Help when distressed
- When the group begins to engage in unrelated conversation, recognize and steer the group back into the assigned tasks

How are documents expected to be shared? (e.g. OneDrive, Google Docs, etc.)
- Documents will be shared to the file on OneDrive
- These files will be organized in OneDrive into files related to the projects or assignments at hand

How many days before an assignment is due should everybody have their portion completed for review?
- Each team member should have their portion completed for review one day in advance.

When should team members first notify the group if they are struggling?

- Team members should notify the group as soon as possible if they are struggling to get help from other members
- They may also be encouraged to ask teaching staff or the instructor in the case that group members are unable to accommodate the issue.
- Struggling team members should notify group using the messages app, the main form of communication of the team

5. Individual Team Member Responsibilities

When/how will individual tasks/responsibilities be assigned?

- Individual tasks will either be assigned in class or during meetings or over text. These tasks will then be uploaded on to clickup so they can be easily tracked and managed.

How will the team ensure work is fairly divided and that everyone participates equally?

- Determine as a group how to split work evenly and ensure that everyone feels that they are carrying an equal share

Are there specific roles that all team members have?

- Not yet but this can be determined as a need arises or team members will naturally fall into a certain role
- Matthew will be our lead for onshape/CAD. Kareena will be the lead programmer. Joey will be the lead for building and circuitry. Julia will be the lead for documentation and assist with design.

What specific tasks are team members in charge of?

- Dependent on task at hand
- In general, team members will oversee tasks directly related to their roles as listed above. However, this does not mean they have full responsibility. All team members will be responsible for assisting other members where necessary.

How often will these roles/task rotate?

- Dependent on tasks at hand (roles will be assigned based on strengths)
- Roles will most likely stay the same for the rest of the semester.

6. Conflict Resolution

Suggested Statement: Once the team goals, general member expectations, and individual team member responsibilities have been established, candid, non-threatening discussion must be held when the group or individuals are not meeting the agreed upon terms.

When there is disagreement amongst members, how will the team make decisions?

- Have a civil and reasonable discussion to resolve the problem, put it to a vote if possible

How will team members above be held accountable (be specific!)?

- Team members will check in with each other on the app ClickUp to make sure tasks are completed on time. Additionally, members will be notified when incomplete assignments are past their due date.

How will team members that are not meeting expectations (not contributing to the team effectively) be Addressed?

- With respectful and professional language, team members will calmly discuss any issues regarding contribution and meeting expectations.

How will team members that are not interacting appropriately with team members be addressed?

- Interpersonal issues will ideally be solved internally, but if these efforts are unsuccessful, it could be escalated first to TA, and then to the professor.

How will the team handle resolving issues when a team member is not acting inclusively?

- Interpersonal issues will ideally be solved internally, but if these efforts are unsuccessful, it could be escalated first to TA, and then to the professor.

What are the consequences for violating this agreement (be creative!)?

- The team member in violation will be assigned an additional task for the next group assignment. Said members in violation will also be expected to issue a formal apology to the team collectively which may be expressed at the next group meeting.

When is it okay to redefine goals, expectations, and responsibilities?

- When the group has voted, discussed, or come to an agreement to redefine said goals, expectations, and responsibilities, it is acceptable. This agreement does not need to be unanimous, though the newly defined goals, expectations, and/or responsibilities must be understood by all members before proceeding with carrying them through.

When will UTAs, GTAs, or the instructor become involved?

- Only if the team is unable to resolve an issue after multiple attempts.

7. Expectations of Faculty and GTAs

Suggested Statement: If a team member fails to live up to this agreement, the situation may be reported to the staff, but the team will still be responsible for submitting a completed assignment. Staff will be available to meet with teams to resolve issues.

8. Team Signatures

Name: Joseph Davancaze

Name: Matthew Allen

Name: Julia Kucaric

Name: Navneet Kaur