HydroGro 2.0

by

Science With Style

Final Proposal

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Section U

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Executive Summary

The Science with Style team's goal is to empower English and Spanish speaking Wheat Ridge residents over 65 years in age who live in food desert regions and rely on food stamps to utilize a self-sustaining plant growing system. The team's proposed solution, HydroGro 2.0, is an elegant three-tiered, automated, hydroponic (soilless) growing system.

HydroGro 2.0 is simple, lightweight, automated, and collapsible. The stakeholder does not need to have any knowledge of how to grow plants to be able to use the system. A pump system keeps the water levels in the hydroponic bottles at the correct height and the use of a timer and pump system limits the maintenance required on the part of the stakeholders. The collapsible design makes HydroGro 2.0 easy to transport and adapt to the stakeholders space requirements. Because HydroGro 2.0 is lightweight, it it easy for the stakeholders to transport.

Using HydroGro 2.0 has many benefits for the stakeholder including savings of up to $215.08 over two years, health benefits of improved access to nutritious food options, and time saving since they will no longer need to travel outside of their food desert area to find fresh vegetables.

The majority of HydroGro 2.0 will come pre-assembled for safe installation and use and will partially utilize materials that can be easily sourced in the Wheat Ridge neighborhood.

HydroGro 2.0 includes five separate subsystems that function in unison to form a self-sustaining growing system:

- Structure: holds the reservoir in its base and supports the hydroponic bottles
- Reservoir: stores the water and nutrients
- Nutrients: provides nutrition to the plants
- Tubing: transports water and nutrients to the hydroponic soda bottles
- Hydroponic soda bottles: provides a growing environment for the plants

The primary interfaces between the subsystems include:

- Interfaces between the structure, reservoir and hydroponic bottles
- Interface between the reservoir and the nutrients
- Interface between the tubing and the reservoir
- Interface between the tubing and the hydroponic soda bottles

Each of the individual subsystems as well as the interfaces between them were tested extensively by the Science with Style team. After many design iterations, the final product, HydroGro 2.0, emerged.

This report describes the details of HydroGro 2.0 and the tests performed to validate that the solution is viable.

Table of Contents

List of Figures

List of Tables

List of Appendices

1 Introduction

This report describes HydroGro 2.0, a three-tiered, automated, hydroponic growing system proposed by Science With Style to enable people living in food deserts to produce their own vegetables. The purpose of this document is to demonstrate the team's solution's superiority compared to existing methodology in regards to efficacy, efficiency, and feasibility. Additionally, this report documents how the team validated that their proposed solution will function properly and meet their target stakeholders' needs through continual analysis and iterating.

The report begins with an overview of the team's design, and then describes the benefits and value of the team's proposal. The proposed solution description also includes assembly explanations with pictorial instructions and a summary of the operations and maintenance procedures for HydroGro 2.0. The proposal then analyzes the possible risks associated with the solution and outlines how the team plans to mitigate them. The report continues with concept validation, analyzing the team's testing, research, and works-like prototype. The team's overall concept and design as well as proposed next steps are highlighted in the conclusion. The bibliography and the appendices provide supplementary content including production drawings, additional testing and research validations, and usage instructions.

1.1 Problem Background

Food Desert Heros (FDH) is calling for a proposal to empower those living in food desert regions to grow their own supplemental supply of fresh food. A food desert is an area where access to nutritious and healthy food options, such as fruits and vegetables, is limited, too expensive, or nonexistent due to a lack of grocery stores and farmers markets within a convenient walking distance [1]. People living in food deserts are often rely on fringe food retailers and discount stores that provide a wealth of high-fat, processed foods, contributing to higher rates of obesity and diabetes in those areas [2]. FDH is seeking a food-production system that can be implemented in a small area without access to ground soil. The intended design must be sustainable, human-centered, and scalable so that it could reasonably be put into place. A minimum of three types of food must be produced (Appendix B contains the full Call for Proposals text).

1.2 Problem Statement

The team's goal is to empower English and Spanish speaking Wheat Ridge residents over 65 years in age who live in food desert regions and rely on food stamps to utilize a self-sustaining plant growing system. The majority of HydroGro 2.0 will come pre-packaged for safe installation and use and will partially utilize materials that can be easily sourced in the Wheat Ridge neighborhood. The net cost will be neutral or better after a two years of harvest and will include features that consider the potential physical limitations of the target stakeholders.

1.3 Stakeholder Identification and Analysis

During the User Empathy Experience in the Wheat Ridge food desert, the team noticed a significant number of older residents; thus, the team chose to target stakeholders over the age of 65 who live in the food desert in Wheat Ridge, Colorado, as identified by the United States Department of Agriculture Economic Research

Service [3]. These stakeholders may be English or Spanish speaking, and rely primarily on the Supplemental Nutrition Assistance Program to obtain their food. According to the United States Census Bureau, 8.6% of households in Wheat Ridge rely on food stamps, and 22.6% of the households receiving food stamps are people over the age of 60. Furthermore, Spanish is the language spoken at home in 7.7% of Wheat Ridge households [4].

While HydroGro 2.0 was designed for this specific stakeholder group, there are other stakeholder groups other than Wheat Ridge residents over the age of 65 who are impacted by the team's proposed solution. Store owners and food distributors in the area will be affected as the residents who choose to grow their own vegetables will most likely purchase less of those products from stores. Local health care providers and government health officials will also be impacted as an increase in healthy food options will most likely better the health of those using HydroGro 2.0. Food Desert Heros also has a stake in the team's proposed solution; the team's solution is being represented by the company, and they will be held responsible if any complications arise. Finally, all suppliers and distributors associated with the production of HydroGro 2.0 have a financial interest in the team's proposed solution.

2 Proposed Solution

2.1 Overview

The team's proposed solution is a three-tiered hydroponic soda bottle system called HydroGro 2.0. A model of HydroGro 2.0 is shown in Figure 1 (full production drawings are included in Appendix A). HydroGro 2.0 includes five separate subsystems (see Figure 2) that function in unison to form a self-sustaining growing system. It features a single reservoir at it's base, with tubing connecting the reservoir to up to twelve soda bottle systems. The user-made soda bottle systems sit in the individually-cut holes in the three-tiered base. Water and nutrients are pumped into the soda bottles on the top tier, and then flows from top tier into the second and third tiers of bottles and then back into the reservoir. Bibb lettuce, spinach, and snow peas will be grown in this system.

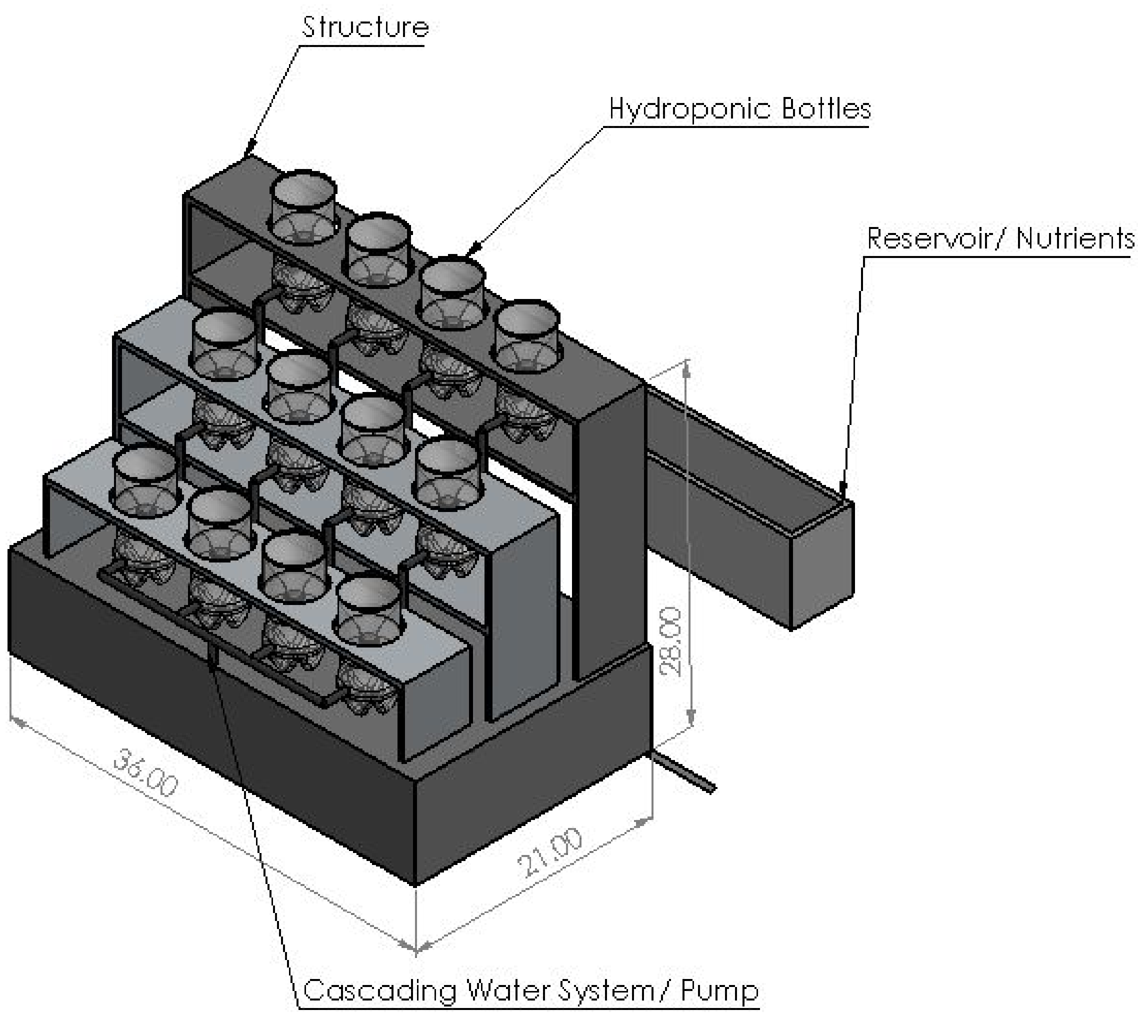

Figure 1: Full system diagram (Artist: C. Cordero)

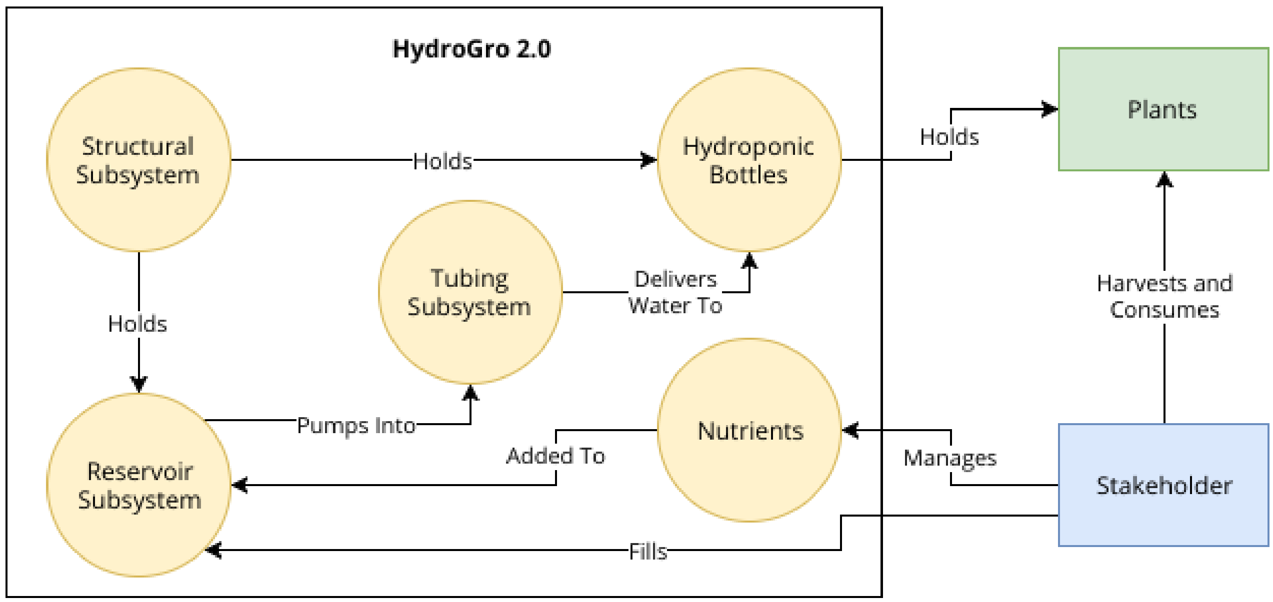

Figure 2: HydroGro 2.0 subsystem relationships (Artist: S. Evans)

2.2 HydroGro 2.0 Functionality and Key Components

HydroGro 2.0's five subsystems, the soda bottles, tubing, reservoir, nutrients, and structure all function in unison to deliver a product for the stakeholder. In this section, the team describes the separate subsystems and how they function together to allow the stakeholder to grow lettuce, spinach, and snow peas.

The first subsystem is the hydroponic soda bottle subsystem. Two litre bottles are used since they can be sourced by the stakeholder from their food desert area with ease. The bottles provide the growing environment for the overall system and act as the intermediary between the water-nutrient subsystem and the plant. Water and nutrients are pumped through the tubing system to the bottom of the bottles, and this water-nutrient mixture is carried to the plant by a wick which controls the amount of water and nutrients that are delivered to the plant, as shown in Figure 3. The plant is placed in the top half of the bottle along with gravel and cotton batting that function as a substrate for the plant's roots to "hook" into. To eliminate algae growth, the bottle will be wrapped in aluminum foil to block out sunlight.

The stakeholder is expected to construct their own hydroponic soda bottle systems using materials that can be easily sourced in their homes and neighborhood. A specialized tool (see Figure 4) will be provided to make the assembly process easier for the stakeholder.

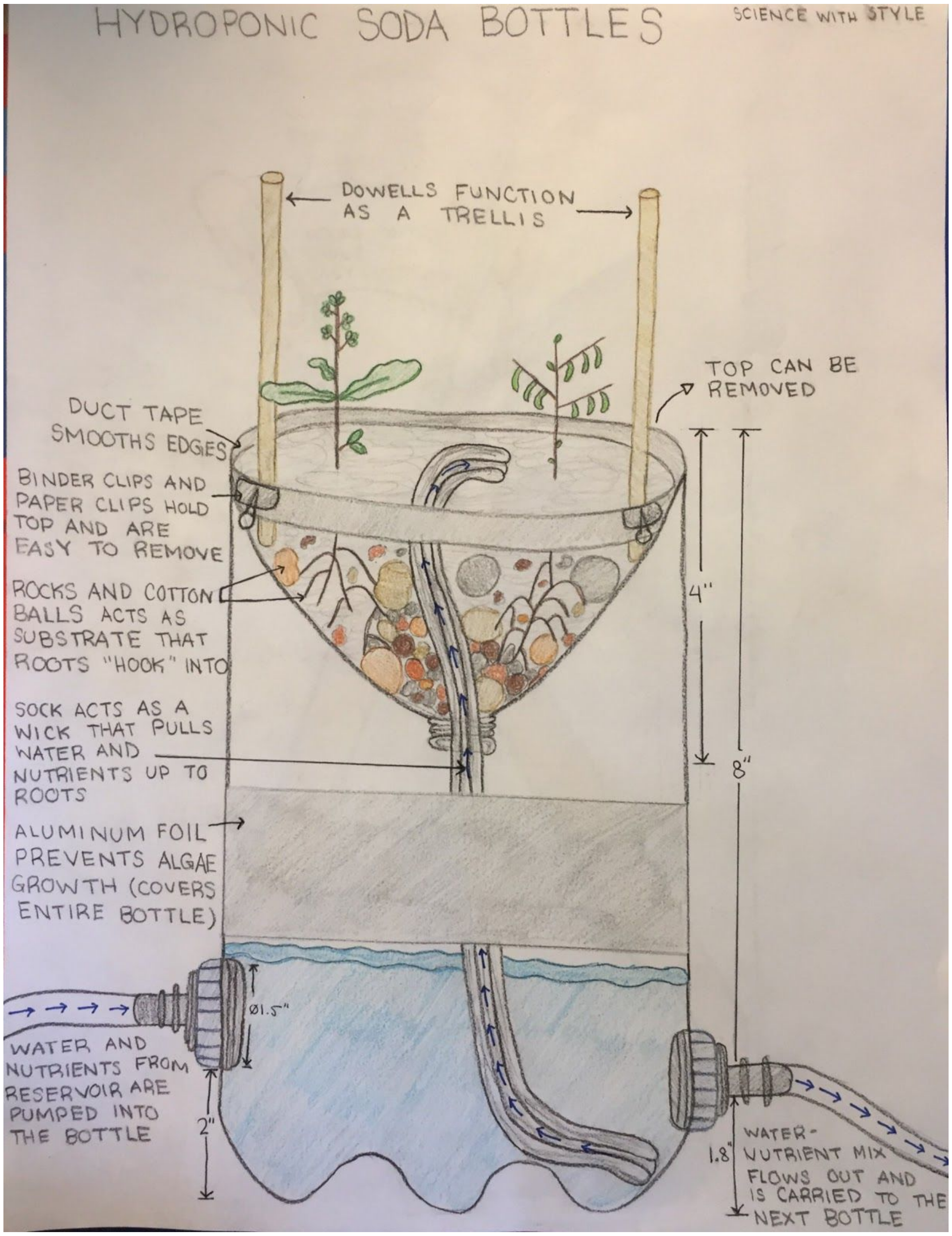

Figure 3: System diagram of the hydroponic soda bottle system (Artist: L. Nield)

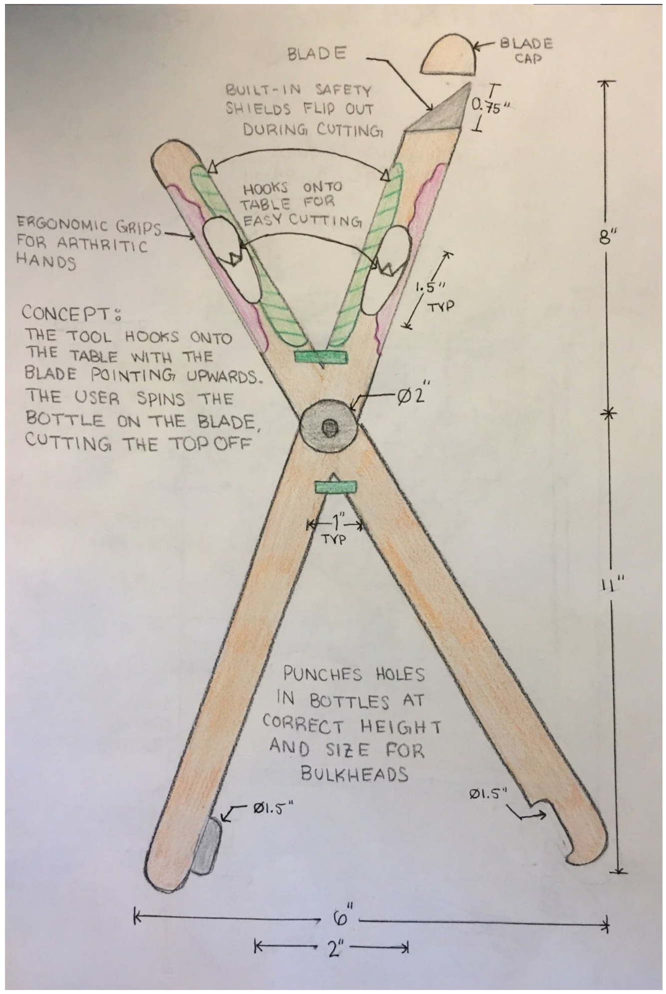

Figure 4: Specialized bottle-making tool (Artist: L. Nield)

The second subsystem, the tubing subsystem, is the sole mechanism for transporting nutrients and water from the reservoir to the hydroponic soda bottles. This subsystem is comprised of tubing connecting the pump to the top four bottles as well as tubing between the bottles on each step of the structure. Water flows from bottle to bottle by the force of gravity, as shown in Figure 5. The tubing is connected to each bottle by a bulkhead. The bulkheads will be at different heights to set a maximum height of water for the bottle to ensure it doesn't overflow. Water from the lowest row of bottles will flow back into the reservoir to complete a circulating system. The tubing used is ½ inch plastic tubing, as it is cost effective and allows for a sufficient amount of water to be pumped throughout each bottles.

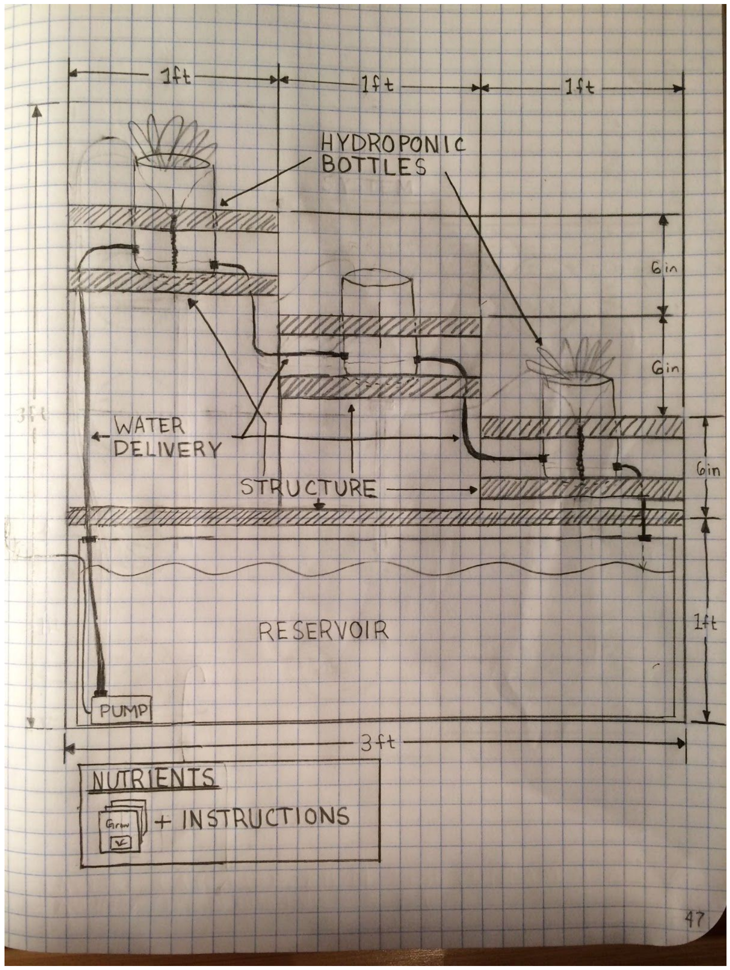

Figure 5: Hydroponic bottles connected via the tubing subsystem (Artist: S. Evans)

The third subsystem is the nutrients subsystem which has two components: detailed instructions on how to properly add nutrients and pre-measured nutrient containers. The team's proposed container is similar to a pill holder, but instead of labeled per-day, this container is labeled per-week. As most of the potential stakeholder have seen or used a pill holder, this container was chosen since the design motif is familiar to the stakeholders. (Appendix C contains information on the tests performed to arrive at this design.) The nutrient solution chosen is designed for circulating systems, which helps prevent bacteria buildup and works well HydroGro 2.0's design. The instructions will located on the reservoir door so that they are easy to see and available whenever needed. They will include information about what the user should look for to ensure proper plant growth and will explain how to determine if the plant is over-nourished or under-nourished and provide a guide on the proper steps to take in order to solve the situation. (Appendix D contains the Usage Instructions that will be provided.)

The fourth subsystem is the reservoir which holds the nutrient-rich water and the pump which automates the system. The reservoir used will be a Sterilite® 7 gallon clear storage tote. The team chose this reservoir since it is relatively lightweight allowing the stakeholder to move it easily, but it is also large enough that there will be about 3 gallons of excess water after all bottles are filled. There will be a minimum fill line for the stakeholder as well as a recommended fill line to help the stakeholder know how much to fill the reservoir. The reservoir will be housed inside the structure's base, and will be able to be accessed by a door as shown in

Figure 1. The pump used in the reservoir is the ECO-132 Submersible Pump, which pumps the water up to the top four bottles. In the production version, a timer that turns the pump on and off will be included. This timer will allow the stakeholder to decide when to run the pump with ease. To clean the reservoir, the stakeholder will need to disengage the pump and timer and remove the reservoir to clean it out with water.

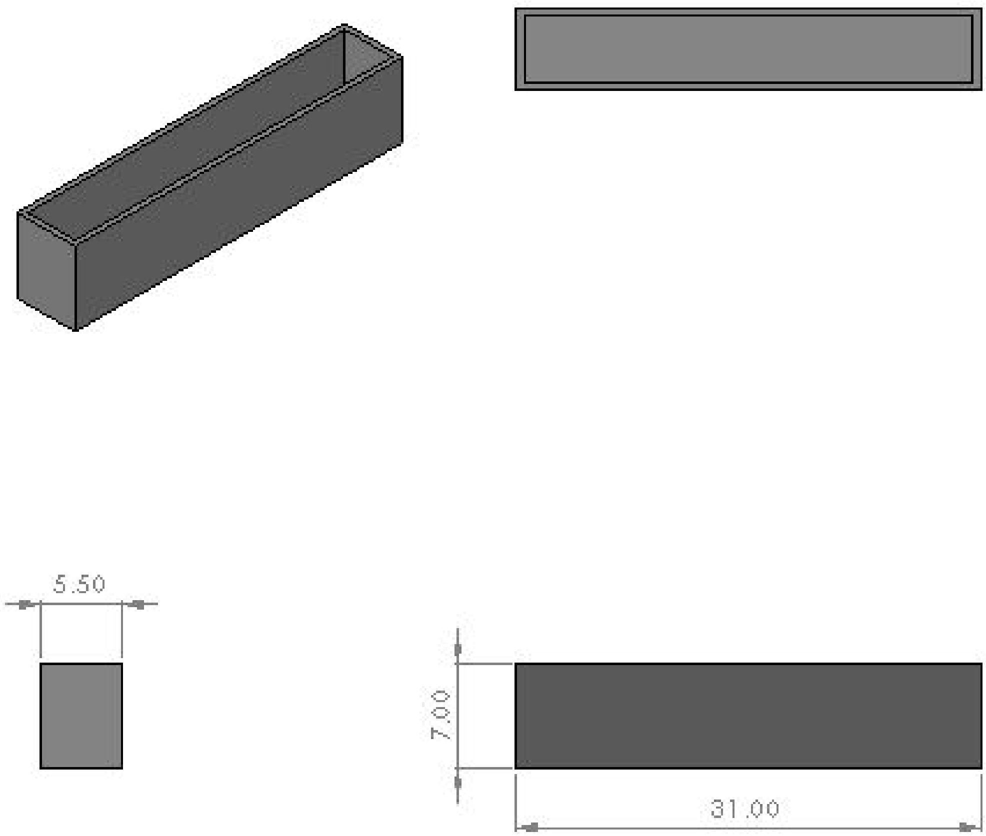

Figure 6: The reservoir subsystem (Artist: C. Cordero)

The fifth and final subsystem is the structural subsystem. The structure holds all of the components of the hydroponic growing system in a compact, lightweight, sturdy, and cost-effective manner. The structure is a three step collapsible design that integrates with the water reservoir and hydroponic bottles as shown in Figure 1. In the final product, the structure will be made out of plastic. The team chose this material because it is cost-effective, strong, lightweight, and waterproof. The collapsible design allows the stakeholder to easily move each piece of the system individually increasing the versatility of the solution. There will be holes on the front and back of the structure for tubing and the pump's power cord. For example, if the stakeholder only wants to grow one set of plants, they can use only one rack of bottles.

2.3 Product Assembly

The structure and water system will come pre assembled, while the stakeholder will have to construct the hydroponic soda bottles using materials that can be easily sourced in the stakeholder's home or in the surrounding neighborhood. The structure is collapsible and will be packaged in an Ikea-like system so that the user can assemble it with ease.

2.3.1 Stakeholder

The Science with Style team designed HydroGro 2.0 to be quick and easy to assemble. HydroGro 2.0 comes completely pre built and contained within the reservoir holder. This minimizes the time required between when the stakeholder receives the product and the time of use. HydroGro 2.0 is designed to be assembled in 1 hour or less.

To construct HydroGro 2.0, the stakeholder must first remove the individual pieces from the reservoir holder. Once all pieces are removed, the stakeholder will need to place the reservoir holder flat on the floor or on a table near a good source of light. Next, they must place the 3 bottle holding racks in height order from front to back on top of the reservoir holder.

After the structure is set up, the stakeholder must make twelve hydroponic bottles. As noted earlier, HydroGro 2.0 will include a specialized tool for making the bottles which will make the construction much easier for the stakeholder (see Figure 4).

For each bottle, the stakeholder will need to source a 2-litre bottle. Then they will need to cut the top off of the bottle and apply duct tape the edge to reduce the cutting hazard. Next, the stakeholder must cut two 1 ⅛" holes through the bottle 2" from the bottom of the bottle. Lastly, the stakeholder will need to attach the bulkheads to the two holes and hand tighten the bulkhead locknut to seal the hole. After the stakeholder constructs the bottles, they can be placed into the cutouts in the structure.

After constructing the bottles, the stakeholder must connect the tubing. The tubing will come completely pre-cut so the stakeholder will not need to cut anything. The stakeholder must first attach the input and output tubing to the back of the top rack bottles and the front of the bottom rack bottles, respectively. Then, the stakeholder will need to attach the shorter sections of tubing to connect the bottles on the top rack to those on the middle rack and connect the bottles on the middle rack to the lowest rack.

Once the stakeholder has connected all of the tubing and checked that the connections are watertight, they can place the pump into the reservoir. The stakeholder must then place the reservoir into the reservoir holder, connect the input tube to the pump, and ensure that the drain tube is pointed into the reservoir. The stakeholder must then fill the reservoir to the fill line and add one unit of nutrients to the reservoir. Lastly, the stakeholder needs to connect the pump's power cord to the timer and set the timer.

The stakeholder must then turn the pump on to start filling up the bottles, if the water level goes below the top of the pump while the bottles are filling, the stakeholder needs to add more water to the reservoir.

As the pump is filling the bottles, the stakeholder needs to place the wick, rocks, cotton balls, and seeds in each of the hydroponic bottle tops. After each of the bottle tops is finished, the stakeholder can place them into their respective bottle bottoms. Once all of the bottle tops have been filled and the water has filled the hydroponic bottles, the construction of HydroGro 2.0 is complete.

2.3.2 Factory

The pieces of HydroGro 2.0 will be constructed in a large-scale factory. The construction process will involve cutting plastic, cutting and assembling tubing, and packaging HydroGro 2.0. To reduce the chances of human errors on the production line, the process will occur with minimal human interaction on the assembly line.

The first part of construction will be casting the shelfs and reservoir holder. This will be done by using molds of each component of HydroGro 2.0 and pouring molten plastic into each one to create a near-perfect reproduction each time. The pieces will then be removed from their molds and will move on to the packaging stage of the construction process.

At the same time, the tubing for the water distribution system will be cut to length and the intake and drainage tubing will be assembled. After all of the tubing has been cut and assembled it will placed within the reservoir and move to the packaging stage.

At the packaging stage the bottle holding racks and the reservoir (with the tubing, bulkheads, and pump inside) will be placed within the reservoir holder. At this point, HydroGro 2.0 is completely contained within the reservoir holder and is ready to be shipped to the stakeholder.

2.4 Interfaces

There are five major interface points between the five subsystems of HydroGro 2.0. There are also four external interfaces related to HydroGro 2.0. All of these interfaces are visualized in Figure 2.

2.4.1 Internal Interfaces

The structural subsystem, which consists of the three hydroponic bottle holding racks and the reservoir holder, has two primary interfaces. The first interface is with the reservoir subsystem. HydroGro 2.0's carrying case is designed to house the reservoir underneath the rest of the system during normal operation. The other interface is with the hydroponic bottle subsystem. The structure holds the hydroponic bottles in place and upright, which prevents them from sliding off of the shelves.

In addition to the interface with the structural subsystem, the reservoir subsystem interfaces with the nutrients subsystem and tubing subsystem. The nutrients are placed directly into the water in the reservoir and the water is then pumped from the reservoir into the tubing subsystem.

The last internal interface is the interface between the tubing subsystem and the hydroponic bottles. This interface (shown in Figure 7) consists of the bulkhead connections where the tubing connects to the wall of the bottles.

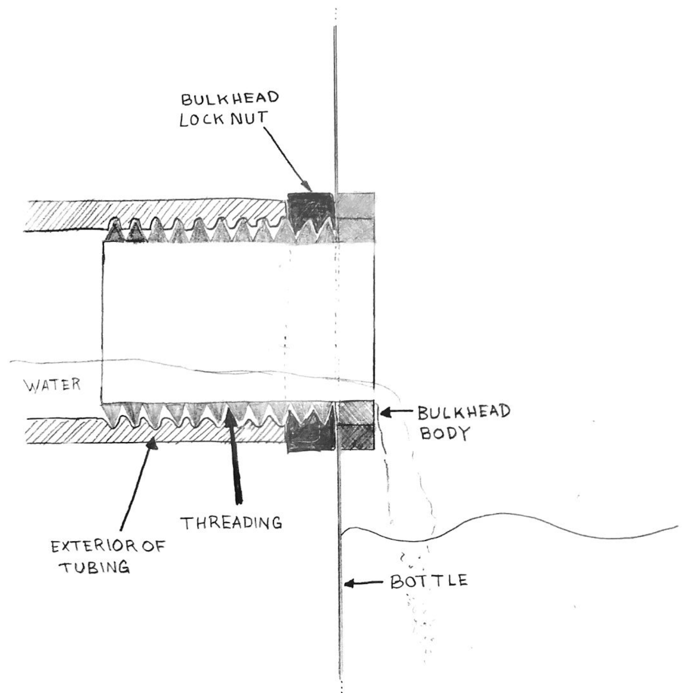

Figure 7: Interface between hydroponic bottle and tubing subsystem (Artist: S. Evans)

2.4.2 External Interfaces

In addition to the internal interfaces, HydroGro 2.0 has two stakeholder interface points, one with the nutrients subsystem and the other with the reservoir subsystem. The stakeholder fills the reservoir with water and must replenish the nutrients by pouring a new packet of nutrients into the reservoir.

HydroGro 2.0 also interfaces with the plants. The hydroponic bottle subsystem holds the plants and provides water to them via the wicking system. The stakeholder also interacts with the plants when they harvest and eat them.

2.5 Value Proposition

The Science with Style team's goal is to have the net cost of HydroGro 2.0 be neutral or better after two years of harvest. To determine if this goal was met, the team took into account the cost of the vegetables that HydroGro 2.0 will produce (bibb lettuce, snow peas, and baby spinach) as well as the cost for the stakeholder to get to the grocery store to buy the produce. Table 1 contains a materials list and cost estimation for HydroGro 2.0 over the course of two years. The final cost for the stakeholder is between $148.23 and $172.47+, depending on their ability to source the materials to make the hydroponic soda bottle systems.

Table 1: Materials List and Cost Estimation For HydroGro 2.0				
Item	**Notes**	**Quantity**	**Cost[1]**	**Total**
Plastic	Price is per pound	1	$0.20	$2.00
Latches		2	$2.25	$4.50
Hinges		2	$2.50	$5.00
Reservoir	~5 gallons	1	$4.32	$4.32
ECO-132 Submersible Pump		1	$11.32	$11.32
Tubing	25 ft	1	$11.00	$11.00
Jack's Professional Hydro Feed	Price is per tsp	520	$0.08	$41.60
Soda Bottles		12+[2]	$0 - $1.00[3]	$0 - $12.00+
Gravel/Rocks	Quantity is per pound	1	$0	$0
Sock/Washcloth		2+	$0 - $1.00	$0 - $2.00+
Cotton Balls		1+	$0 - $1.47	$0 - $1.47+
Binder Clips/Paper Clips	Price is per box of 100	24+	$0 - $1.39	$0 - $1.39+
Duct Tape	Price is per roll	1+	$0 - $2.39	$0 - $2.39+
Paper Towels	For seed germination; Price is per roll	1+	$0 - $1.50	$0 - $1.50+
Aluminum Foil	Price is for a roll	1+	$0 - 3.49	$0 - $3.49+
Bulkheads		24	$1.00 [5]	$24.00
Specialized Tool		1	$10.00	$10.00
Lettuce Seeds	Packet contains 500 seeds	1	$2.00 [6]	$2.00
Spinach Seeds	Packet contains 250 seeds	1	$2.00 [6]	$2.00
Pea Seeds	Packet contains 130 seeds	1	$1.50 [6]	$1.50
SmartPool Programmable Pump Timer		1	$28.99	$28.99
Total cost of HydroGro 2.0			**$148.23 - $172.47+**	

After an initial month of no production when the plants are maturating, HydroGro 2.0 is expected to produce between ½ lb and 1 lb of each vegetable type every month. This amount may vary depending on how many

[1] Cost determined for two year+ use.
[2] Quantity is for twelve bottle systems. Over time, the user may choose to replace their systems.
[3] HydroGro 2.0 is designed so that the user can find these items in their homes instead of purchasing them.

seeds the user chooses to germinate and the success of the crop yield. The prices of each vegetable type from the nearest Safeway outside of the Wheat Ridge food desert are as follows [7]:

- Bibb lettuce: $2.50/lb
- Baby spinach: $11.84/lb
- Snow peas: $8.96/lb

Additionally, the cost of public transportation is $5.20 for a round trip [8]. Assuming a yield of half a pound of vegetables per month, it would cost the stakeholder $387.55 (see Calculations below) to purchase an equivalent amount of food from Safeway. Assuming a yield of one pound of each vegetable per month, the stakeholder would be paying $655.50 (see Calculations below) for an equivalent amount of food. Even if the yields are unexpected low for many months, HydroGro 2.0's cost is still significantly lower compared to the cost of buying the vegetables at a grocery store outside of the food desert area. Thys, HydroGro 2.0's net cost is projected to be significantly better after just two years of harvest.

HydroGro 2.0 also has other advantages in addition to the monetary benefits. Having the system in the stakeholder's home means that they do not have to walk or take public transportation to the Safeway or another grocery store to buy their vegetables. Since our target stakeholder is over the age of 65, this trip could potentially be very taxing. The team noticed during their User Empathy Experiment that even walking to the bus station with all of their groceries was a challenge, especially in the summer heat. With HydroGro 2.0, the stakeholder can comfortably grow their vegetables indoors and will not have to face the sweltering Colorado summers and freezing winters while trying to find a store that sells fresh produce.

Going to the grocery store also has time costs. It would take approximately 15 minutes each way for the stakeholder to get to Safeway using public transportation. Assuming that they spend 30 minutes in store, the stakeholder would be spending at least an hour every month just to buy their vegetables. HydroGro 2.0 only requires minimal maintenance so the stakeholder can spend significantly less time every month tending to their plants.

Growing vegetables in HydroGro 2.0 will also provide the stakeholder with a better quality of life. Having healthier food options will most likely improve the health of the stakeholder, since their diet currently lacks foods that contain vital nutrients needed for good health. Also, since most of the stakeholders are presumably retired, HydroGro 2.0 provides them with something to focus on during the day if they wish. However, if they do not want the responsibility, the system also does not need extensive maintenance, making it ideal for the lifestyle of any stakeholder.

Calculations:
Bibb lettuce: $2.50/pound Baby spinach (only comes pre-packaged): $0.74/ounce = $11.84/pound Snow peas (only comes pre-packaged): $0.56/ounce = $8.96/pound Transportation = $5.60 for day pass/two way

For two years:

After a month of maturation, the plants can be continuously harvested → 23 months

For half a pound of each vegetable a month:

$$\frac{\$2.50}{2} \times 23 + \frac{\$11.84}{2} \times 23 + \frac{\$8.96}{2} \times 23 + \$5.60 \times 23 = \$387.55$$

For a pound of each vegetable a month:

$$\$2.50 \times 23 + \$11.84 \times 23 + \$8.96 \times 23 + \$5.60 \times 23 = \$655.50$$

2.6 Operations and Maintenance Summary

HydroGro 2.0 is designed to minimize the time required to maintain the system. There are, however, some initial setup steps (shown in in Figure 8) and some recurring activities required to keep HydroGro 2.0 running smoothly. The stakeholder will receive detailed instructions explaining the initial setup process, the weekly and monthly maintenance process, and a troubleshooting guide similar to the one shown in Figure 9. Appendix D contains the full instruction text that will be included with HydroGro 2.0.

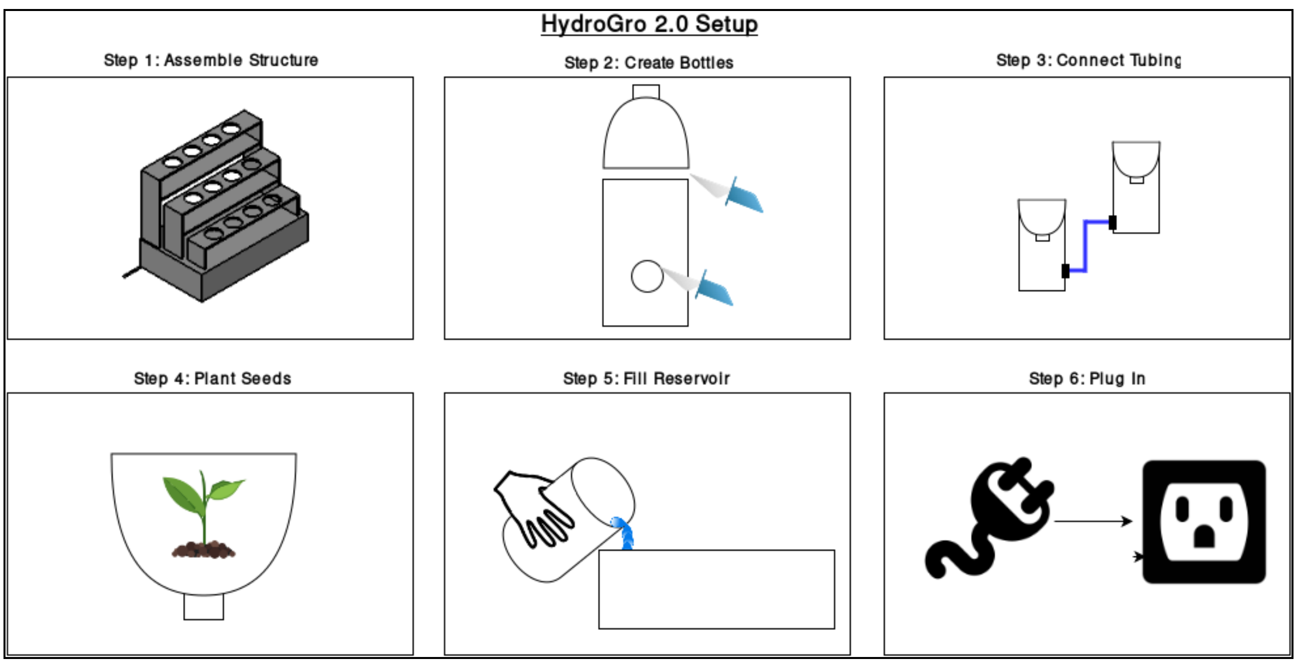

Figure 8: Initial setup steps (Artist: S. Evans)

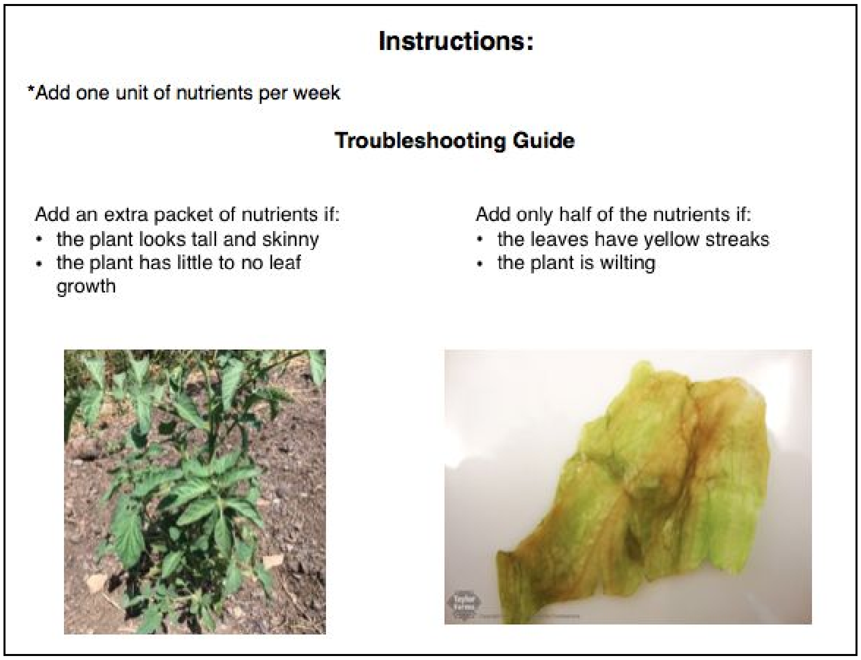

Figure 9: Sample maintenance instructions (Author: L. Peters)

2.7 Risk Analysis and Mitigation Plan

After determining the possible risks associated with HydroGro 2.0, the team determined the magnitude and likelihood of these potential problems and placed the results into Table 2. Table 2 also contains a plan to mitigate each risk.

Table 2: The Team's Risk Mitigation Plan

Risk	Likelihood	Impact	Magnitude	Mitigation Plan
User Error	**Very Likely**	**Major**	**5**	**See Below**
Structural Assembly	Very Likely	Major	5	The team will provide a very detailed and easy to understand instruction packet with the system. These instructions will utilize pictures and text in multiple languages to be accessible to all of the stakeholders.
Nutrients	Likely	Minor	1	The nutrients will come pre-measured with easy-to-understand instructions.
Bottle Assembly	Likely	Major	3	The team will include an easy to use bottle assembly tool, so the stakeholders can make the hydroponic water bottles without risk of injuring themselves.
Structural Weight	Likely	Major	3	The team's design allows for each piece of the structure to be carried separately, enabling the stakeholders to move the

				structure even with their physical limitations.
Language Barrier	Likely	Moderate	2	The team's instructions will be multilingual and will rely on illustrations and color-coding.
Cost	Likely	Major	3	The team has strategically selected their materials and structure as to minimize the cost of the system. The team will also provide a minimal cost maintenance plan for the stakeholder. This "membership" system will deliver new nutrients and seeds to the stakeholder every three months.
Stability	Likely	Major	3	The reservoir stabilizes the structure, preventing it from falling over.
Pump Failure	Unlikely	Moderate	1	The team's design also allows for manual watering.
Incorrect Nutrients	Unlikely	Minor	1	The nutrients will come pre-measured and color-coded to minimize the risk of incorrect nutrient ratios.
Water Contamination	Unlikely	Moderate	1	The reservoir will be made of quality plastic, making punctures less likely. Also, the water tank is in its own drawer under the the hydroponic bottles, therefore reducing the amount of light that reaches it.
Flow rate	Unlikely	Moderate	1	Wick watering ensures that the flow rates do not have to be precise.
Leakage	Very Likely	Moderate	3	The tubing will be high quality, and the bulkheads on the soda bottles will prevent leakage.
Bacterial Growth	Very Likely	Moderate	3	The soda bottles will be wrapped in aluminum foil to reduce the amount of sunlight reaching the water-nutrient mixture. The tubing will also be opaque to discourage the growth of algae.
Nutrient Shortage	Likely	Moderate	2	Included in the price is a nutrient "membership" so that new pre-measured nutrients are delivered to the stakeholder every three months.
Plants Do Not Grow	Unlikely	Moderate	1	Planting multiple seeds in each bottle increases the chances of germination.

Power Loss	Likely	Minor/ Moderate	1.5	While it depends on the duration of the power-loss, there will still be water in the bottles, and the bottles can be manually filled if the blackout is prolonged.
Top of Bottle Falling In	Very Likely	Minor	2	The team will use clips to ensure that the top does not fall into the bottom of the bottle.
Spacing Issues	Likely	Moderate	2	The design ensures that there will be extra space for plants to grow. The team chose plants that grow in confined spaces.
Light	Likely	Moderate	2	The team chose plants that prefer to be grown in partial shade, making a window an ideal light source.
Water Cycle	Unlikely	Moderate	1	The gravitation water flow system will allow the water to circulate.
Fill Reservoir	Likely	Minor	1	The reservoir will contain a fill line to ensure that all the container has the correct amount of water.
Water Fill (Reservoir Access)	Unlikely	Moderate	1	The base of the structure will contain a door that will allow quick access to the reservoir. Instead of carrying the reservoir, the user can use a pitcher to easily fill them.
Cleaning the Reservoir	Likely	Moderate	3	Easier access to the reservoir will allow for easy cleaning. Efforts to reduce bacterial growth will lengthen the time in between cleanings.

3 Concept Validation

In order to ensure that the team's design for HydroGro 2.0 was viable, extensive testing was performed and comprehensive research was completed. This section describes the testing and/or research validations completed for each subsystem.

3.1 Hydroponic Soda Bottles

The team used various tests and research to ensure that the hydroponic soda bottles could successfully house and provide nutrients to the plants and interface with the rest of the system.

3.1.1 Testing Validation

One of the most critical parts of the soda bottle system is its ability to provide a suitable environment for a plant to grow. To test this, the team attempted to grow bibb lettuce in a hydroponic soda bottle system identical to the system seen in Figure 3. While the team was unable to complete this test by the time this writing, Figure 10 shows the plant's progress after two weeks. The successful growth of the plants confirms that the team's hydroponic soda bottle design will work in the proposed final solution and validates the effectiveness of wick watering. This test further confirms that an artificial lighting system is not necessary; both types of plants have shown growth with only a window as a light source. Algae growth in the water in the bottom of the reservoir caused the team to add aluminum foil to the design of the bottle; the aluminum foil will block enough light to inhibit algae and bacterial growth (see Appendix C).

Figure 10: Bibb lettuce growth in the hydroponic soda bottle system (Photo by: L. Nield)

Additional testing was required to verify that the stakeholders can construct the bottle systems on their own. The cost of the proposed solution depends upon the stakeholder's ability to construct the soda bottle systems with materials sourced in their house and neighborhood. To ensure that the team's primary stakeholder will be able to accomplish this, the team enlisted 87-year-old Norma Dwyer to make a bottle growing system. Even with her physical limitations, she was able to construct a successful system in under 10 minutes with ease, verifying that the stakeholder will most likely be able to make the soda bottle systems on their own. The process should be even easier with the team's specialized tool as described in previous sections (see Figure 4).

A crucial function of the soda bottle system is its ability to function with the watering system. The team tested the interfaces between the reservoir, watering system, and bottles using the works-like prototype. While the overall system was functional, there was a large amount of leakage coming from the holes in the bottles. To prevent leakage, the team added bulkheads into the final design to seal the holes. The bulkheads will be included in HydroGro 2.0 package. Further testing (described in depth in Section 3.5) confirmed that the bulkheads successfully prevent water leakage.

Finally, stakeholder feedback caused the team to modify the final design of the bottle systems. The team sent a detailed description of the solution to two potential stakeholders (Judy Dwyer, 65 and Norma Dwyer, 87) to get their feedback on the system. They noted the need for a trellis for the snow pea plants and sprouting strategies and raised concerns about the system's complexity. As a result, the team added an optional trellis made out of dowels or popsicle sticks to the final design. The team will also provide instructions to start the seeds using the damp paper towel method: the stakeholder will wrap the seeds in a damp paper towel 24 hours before transplanting them into the bottle system. Their concerns also influenced the team's decision to go from having four reservoirs with four different nutrient solutions to a single reservoir with one nutrient solution.

3.1.2 Research Validation

The hydroponic soda bottle system is based off of the well-known Kratky method, in which a suspended net pot hydroponic growing system is used for growing leafy vegetables and only requires an initial application of water and nutrients. This system is ideal because additional labor is not required until harvest. A variation of this classic Kratky method is the 4-liter bottle method, which is suitable for lettuce and other short term crops that require less than 4 liters of water during their lifespan. The 4-liter bottle method is very similar to the team's 2-liter hydroponic system. In this system, a 4-liter plastic bottle is filled with water and hydroponic fertilizer and is covered in foil to discourage algae growth. Vegetable seeds are sown and transplanted into a tapered net pot filled with growing medium that is supported by the neck of the bottle. The lower portion of the net pot is immersed in nutrient solution which moistens the entire medium by capillary action; the increasing zone of moist air between the nutrient solution and the net pot encourages plant growth. In Hilo, Hawaii, a 200-gram lettuce plant was produced using this method with only 3-4 liters of nutrient solution [9].

The team's hydroponic soda bottle system is very similar to the Kratky 4-liter bottle method. One major similarity is the use of the wicking method described in the Kratky method. Wick watering works by capillary action. In the hydroponic soda bottle, water and nutrients travel up the wick and keep the potting mix moist. The constant supply of food and moisture contributes to quicker and stronger plant growth than can be achieved by top-down watering methods. For an ideal wicking system, the wicking material must be absorbent and resistant to rotting, such as old socks and washcloths. Furthermore, the growing media needs to be absorbent enough to hold moisture, making a cotton-based growing-substrate ideal [10]. All of the team's research further prove that the 2-liter hydroponic system will work.

3.2 Nutrients

3.2.1 Research Validation

When deciding on which plants to grow, there are three vital conditions to consider: the space necessary for the plant to fully blossom, the optimal temperature range, and the harvest length. The plants grown using HydroGro 2.0 need to be able to grow in a confined space at low temperatures in a relatively short amount of time. The crops chosen for HydroGro 2.0, bibb lettuce, baby spinach, and snow peas, were selected because they meet all three requirements. Lettuce only needs between 6 and 18 inches of space with an ideal temperature range of between 45℉ and 80 ℉" [11]. Additionally, the harvest season for lettuce last between 50-75 days [12]. Similarly, spinach must be placed between 8 and 12 inches apart and grows in temperatures between 35℉ and 75℉ [13]. Peas grow with only 2 inches of spacing, and in temperatures between 41℉ and 73℉, and harvest in only 100 days [14].

After choosing the types of plants to be grown the team's research focused on the nutrients necessary for these specific plants in a hydroponics system. The team decided to use Jack's Professional Hydro-feed since that product has worked well for The Denver Growhaus. The Denver Growhaus produces large amounts of leafy plants such as a spinach and lettuce for the community using only Jack's Professional Hydro-feed with an N-P-K value of 16-4-17. Using this nutrient regimine, each plant needs one tsp of nutrients per gallon. In order for the plants to successfully grow, the pH of the water-nutrient mixture in the reservoir must rest between 5-6 while the ppm of the water lies above 800.

Lastly, the stakeholder must be prepared in case the plants do not grow exactly as the nutrient regimen expects i.e. needing more or less nutrients to remain on a healthy grow cycle. If the plant metabolizes the nutrients too quickly and needs more to bloom, the plant will become tall and skinny with little to no leaf growth. On the other hand, the plant's leaves will turn yellow and may wilt when the plant is supersaturated and needs less nutrients. The Troubleshooting Guide (see Appendix D) contains instructions for the stakeholder to accurately assess and resolve the issue before the plant becomes unsalvageable.

3.2.2 Testing Validation

In order for the plants in HydroGro 2.0 to successfully grow, the pH and ppm of the water-nutrient mixture must fall within tight ranges. Though the nutrients company gives the stakeholder a guide for the amount of nutrients per gallon, the amount of nitrogen, phosphorous, and potassium in tap water can vary and, thus, affect the nutrients. Therefore, the team performed a test comparing the pH and ppm values based on differing concentrations of nutrients until the perfect balance was determined.

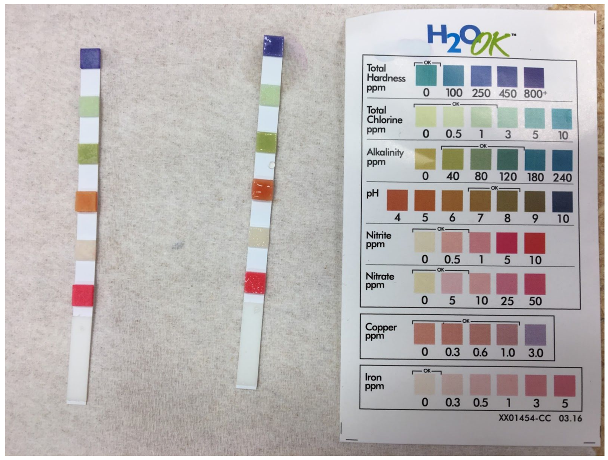

Figure 11: Results from first test (Photographer: L. Peters)

The strip on the left in Figure 11 displays the results for a mixture of 1 teaspoon of nutrients per gallon while the strip on the right displays these values for a mixture of 1 ½ teaspoons per gallon. The top test measures the ppm of the mixture; both strips tested perfectly showing a dark navy blue color meaning their ppm is at least 800. The fourth test from the top indicates the pH in both mixtures. The strip on the right shows a pH closer to four while the strip on the left falls within the ideal range with a pH of five. From this, the team decided to use one teaspoon per gallon rather than one and half teaspoons per gallon.

The team also performed other minor tests as described in Appendix C.

3.3 Structure

The structure of HydroGro 2.0 was pivotal to the system's overall functionality. The Science with Style team conducted multiple tests to ensure that the structure would be capable of supporting the other subsystems.

The first tests conducted did not involve the other subsystems. These tests included testing the amount of weight that the structure could hold and testing the weight of the structure. The amount of weight that the structure could hold was tested by spreading five 5 lbs. weights over each shelf of the structure. Every shelf easily passed this test. Since the structure can be moved in pieces, the team's goal was to make each piece of the structure weight under 30 lbs. The heaviest piece, the reservoir holder, weighed only 16.3 lbs which under the weight objective.

The next stage of testing was conducted with all other subsystems. The structure was tested to make sure it could support the hydroponic bottles and watering system. This was done by setting up the entire HydroGro 2.0 system. During the test the team found that the structure held all of the other subsystems successfully.

3.4 Reservoir

The reservoir is necessary to house the nutrient rich water and pump it up to the highest level of bottles. Without the reservoir, there would be no water for the plants to grow. In order to make sure the reservoir held enough water and the pump functioned well, the team conducted several tests.

The initial reservoir design was a 5 gallon bucket with holes in the side for tubing and other connections. The team then decided that they should instead focus on a collapsable design and house the reservoir underneath the structure. To find a pump that would be able to raise the water up to the top row of bottles (3 ft), the team tested the maximum head height of two different pumps. The first pump the team used was not strong enough to pump to 3 ft, and thus the team chose to test a stronger pump. The new pump was able to raise water up to 4 ft, more than the 3 ft required, and thus the team decided to use the second pump in their final design. The team also needed to choose a reservoir size that would be big enough to fill all the bottles and still have some water left in the reservoir. To test this, the team set up the full HydroGro 2.0 system and used the pump to fill the bottles with water. The team used a 5 gallon reservoir for this test and noticed that the water drained too quickly and had to be refilled in order to keep the water level above the height of the pump. This is inconvenient for our stakeholders, and thus the team decided on a larger reservoir.

3.5 Cascading Water System

The cascading water subsystem is the sole mechanism for transporting nutrients and water from the reservoir to the soda bottles. This subsystem is critical to the overall system because if water and nutrients are not delivered to the bottles, the plants cannot grow and no food can be produced. As such, extensive testing was performed on this subsystem and major iterations were made.

Initially, the cascading water system consisted of four separate water circulation systems. After the team consolidated the nutrient solution, the cascading water system was consolidated down to one pump which transports water to the top row of bottles. Each bottle drains into the bottle below by the force of gravity via another bulkhead and tube.

The most important validation that the team performed was testing the connections between the tubing, bulkheads, and the hydroponic bottles. This test involved constructing hydroponic bottles similar to the ones used in the final product and connecting it to a pump. After running the pump for twelve hours, the team checked for leakage.

In the first attempt, bottles with curved sides for better grip were used. Because of the curvature, the bulkheads were unable to make a good enough seal. For the second attempt, bottles with straight sides were used. This worked better, but some leakage still occurred. The team determined that the leakage was occurring through the threads of the bulkhead so for the next test, thread sealant was used. This worked much better and no leakage occurred for the entire twelve hours. In the works like prototype, bottles with slightly thicker sides were used and the technique for putting holes into the bottles was perfected. Combined, these two factors allowed the team to seal the holes with only the bulkheads without needing to use thread sealant.

3.6 Final Validation Processes

The team created a works-like prototype to further validate HydroGro 2.0's effectiveness. The team was able to remain within the $100 budget when constructing this prototype, as seen in Table 3. After assembling the prototype, the team decided to add several more iterations to the production design. To ensure that the stakeholder puts the reservoir in the correct spot so the water drains properly, the team added slots in the base of the structure to guide where the reservoir should be placed. The team also noticed that the water would not drain back into the reservoir if the tubing went above the bulkheads. To correct this, the design was corrected to put the “drain” tubing in the front of the system instead of in the back to ensure proper drainage back into the reservoir.

After inspecting at the works-like prototype, the team realized that the structure could be made smaller and still fit four bottles in each row. As a result, the team corrected the dimensions of the final design to be smaller. Furthermore, while assembling the prototype, the team found the ½” tubing to be stiff and difficult to manipulate. To make assembly easier, the team replaced the ½” tubing with ⅛” IV line tubing. Even though it would take longer for the bottles to fill up, the overall gain in ease-of-use was deemed to outweigh the cost.

Table 3: Works-Like Prototype Cost

Item	Quantity	Cost	Total
Plywood	1	$10.00	$10.00
Latches	1	$2.95	$2.95
Hinges	1	$1.95	$1.95
Reservoir	1	$4.35	$4.35
ECO-132 Submersible Pump	1	$11.32	$11.32
Tubing (25 ft)	1	$11.00	$11.00
Jack’s Professional Hydro Feed	10	$0.16/tsp	$1.60
Soda Bottles	12	$0.00	$0.00
Gravel/Rocks	50+	$0.00	$0.00
Socks	2	$0.00	$0.00
Cotton Balls	30+	$0.00	$0.00
Binder Clips/Paper Clips	24	$0.00	$0.00
Duct Tape Roll	1	$0.00	$0.00
Aluminum Foil Roll	1	$0.00	$0.00
Bulkheads	24	$2.00	$48.00
TOTAL COST:			**$91.17**

4 Conclusion

As explained in the previous sections, HydroGro 2.0 is superior to existing methods of vegetable acquisition in the Wheat Ridge food desert area. According to the team’s value proposition (Section 2.5), using HydroGro 2.0 will save the stakeholder $215.08 after just two years of harvest. In addition to monetary benefits, HydroGro 2.0 has dietary and time saving benefits. The stakeholder does not have to travel outside of their neighborhood to find fresh vegetables; they can grow them inside their home with little effort. The added nutrients that they will receive by growing their own vegetables will better the stakeholder's health, leading to an improvement in their overall quality of life.

HydroGro 2.0's elegant design is perfectly fitted to the team's stakeholder. It is automated, collapsible, lightweight, and simple. The stakeholder does not have to have any knowledge of how to grow plants to be able to use the system. The pump system keeps the water levels in the hydroponic bottles at the correct height and the use of a timer and pump system limits the maintenance required on the part of the team's stakeholders. The collapsible design makes HydroGro 2.0 easy to transport and adapt to the stakeholders space requirements. Because HydroGro 2.0 is lightweight, it it easy for the stakeholders to transport.

The Science with Style team will continue to experiment with new varieties of fruits and vegetables to grow using HydroGro 2.0, adjusting the design as necessary. Furthermore, the Science with Style team will continue to refine the current design with a specific focus on stakeholder needs and feedback. One major component requiring further refinement is the bottle making tool.

In order to transform HydroGro 2.0 from a works like prototype to a fully developed product for consumers, the Science with Style team recommends that a payment and nutrient plan be implemented to reduce the initial capital required to buy HydroGro 2.0. This payment plan will allow the stakeholder to pay for the unit over time, much like a lay-away program or a phone payment plan. In addition, a nutrient plan will be provided so that the stakeholder does not have to remember to buy nutrients; this is similar to the ink cartrige plan provided by HP®. Every three months, the stakeholder will be sent a new supply of nutrients.

The Science with Style team will also have to do marketing to inform potential buyers of the benefits of HydroGro 2.0. This would involve educating potential stakeholders about hydroponics and launching an advertising campaign explaining the SLAC (Simple, Lightweight, Automated, Collapsible) properties of HydroGro 2.0.

The Science with Style team is excited about the future of HydroGro 2.0 and is looking forward to bringing their solution to the homes of many Wheat Ridge residents and improving the quality of their stakeholders' lives.

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Interviews conducted:

Email from Gavin Vitt, Daily Harvest Aquaponics, Colorado Springs, Colorado, October 30,2016.

Phone Call from Shannon Harper, Hydroponics Expert, Growhaus, Denver, Colorado, November 1, 2016 at 12:30 p.m.

Email from info@jrpeters.com, JR Peters Inc., Allentown, Pennsylvania, November 14, 2016.

Appendix A: Production Drawings

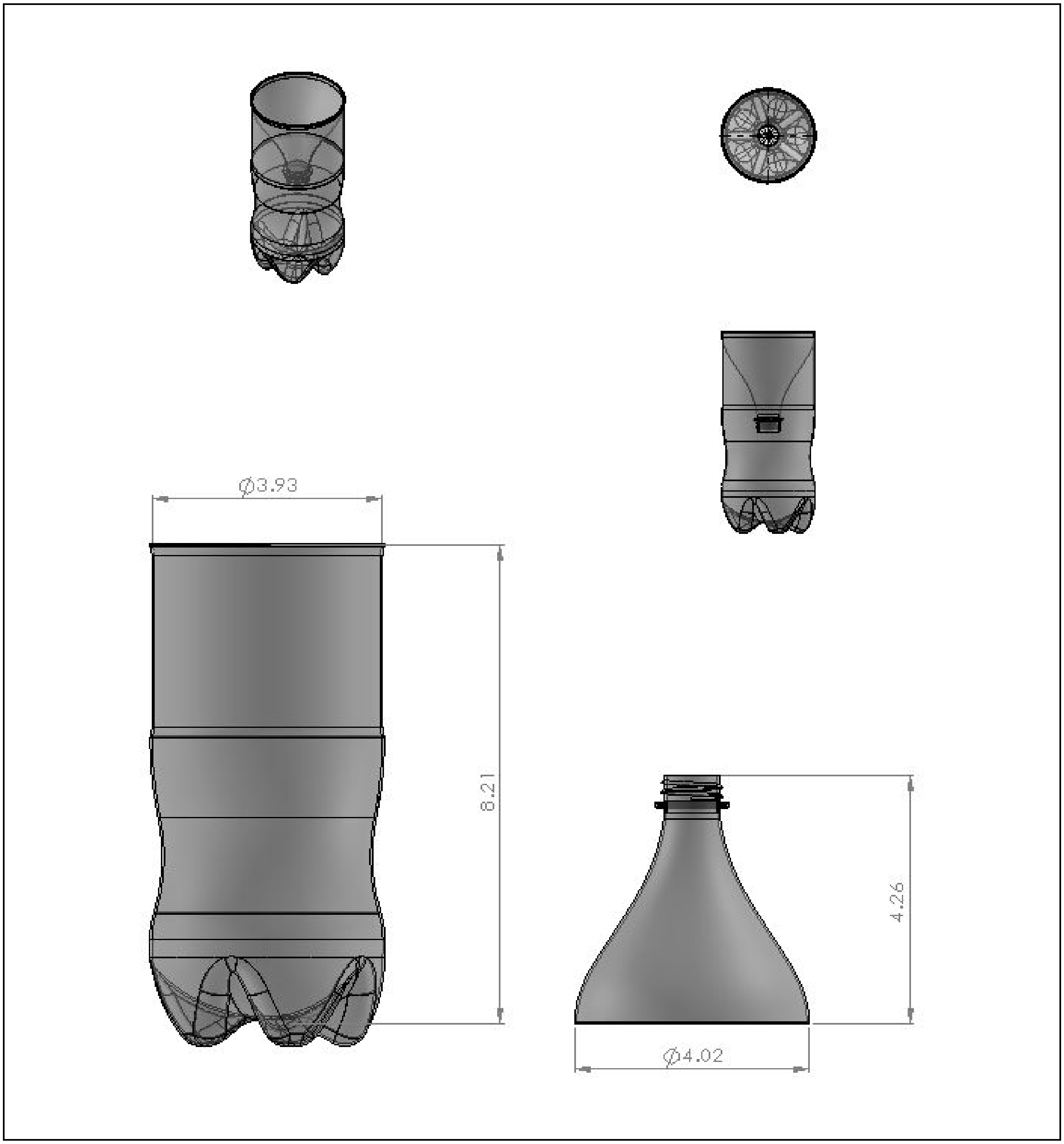

Figure 12: Bottle construction dimensions (Artist: C. Cordero)

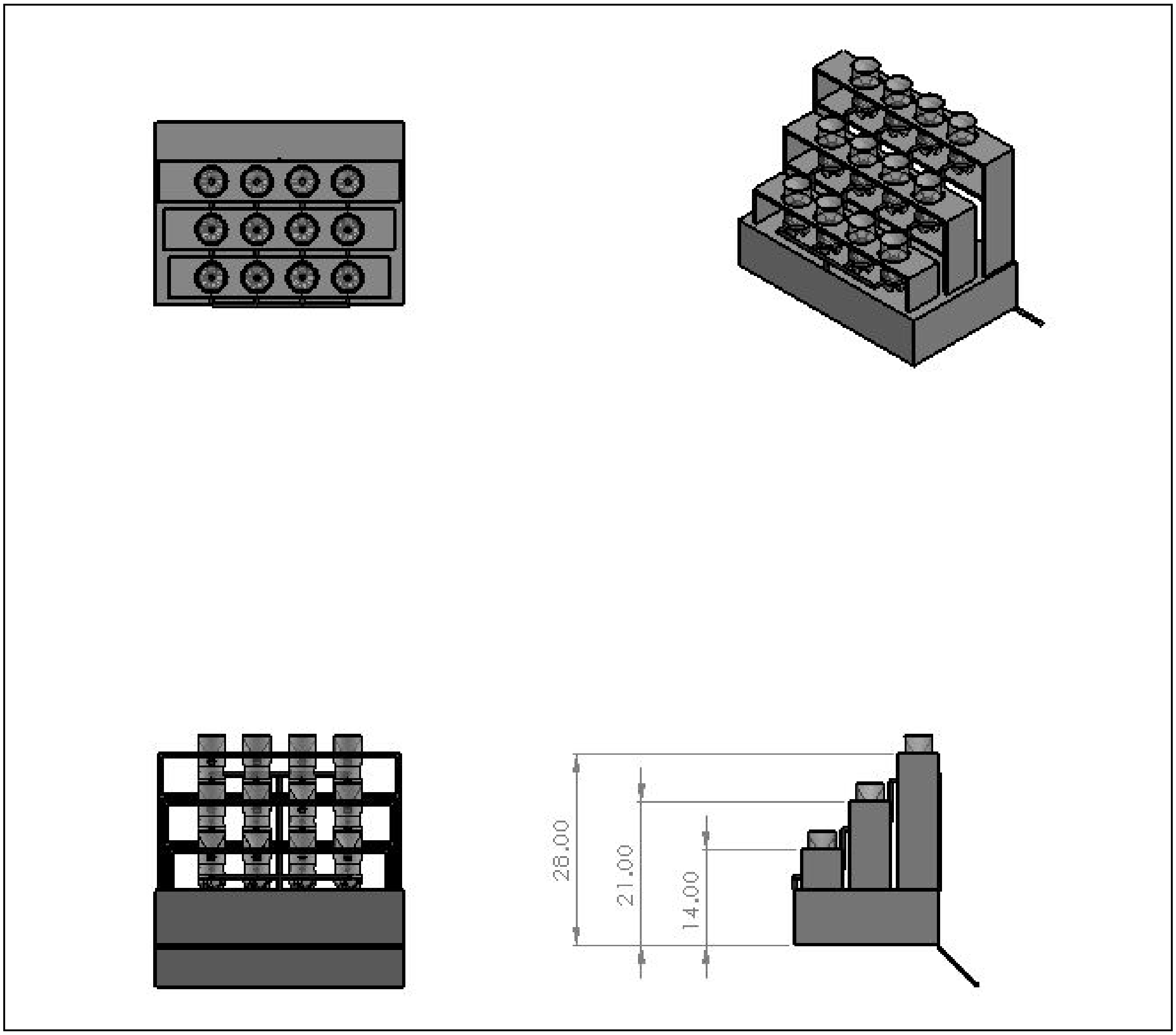

Figure 13: Full isometric view (Artist: C. Cordero)

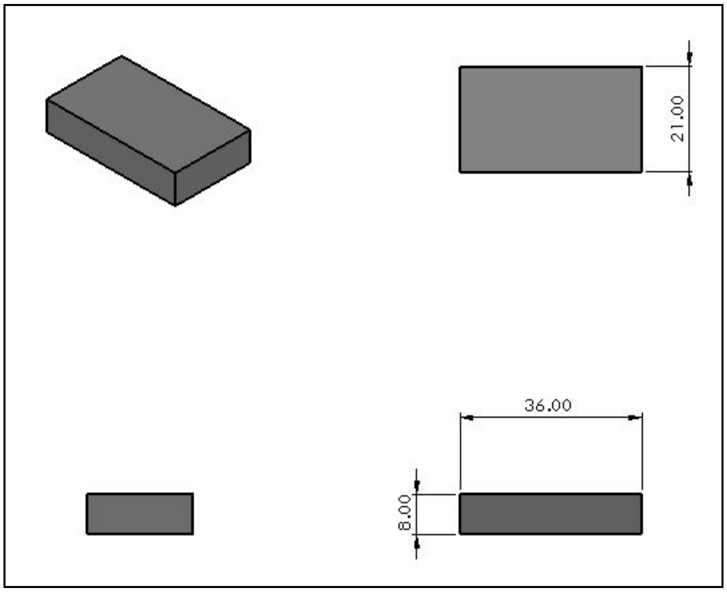

Figure 14: Reservoir holder dimensions (Artist: C. Cordero)

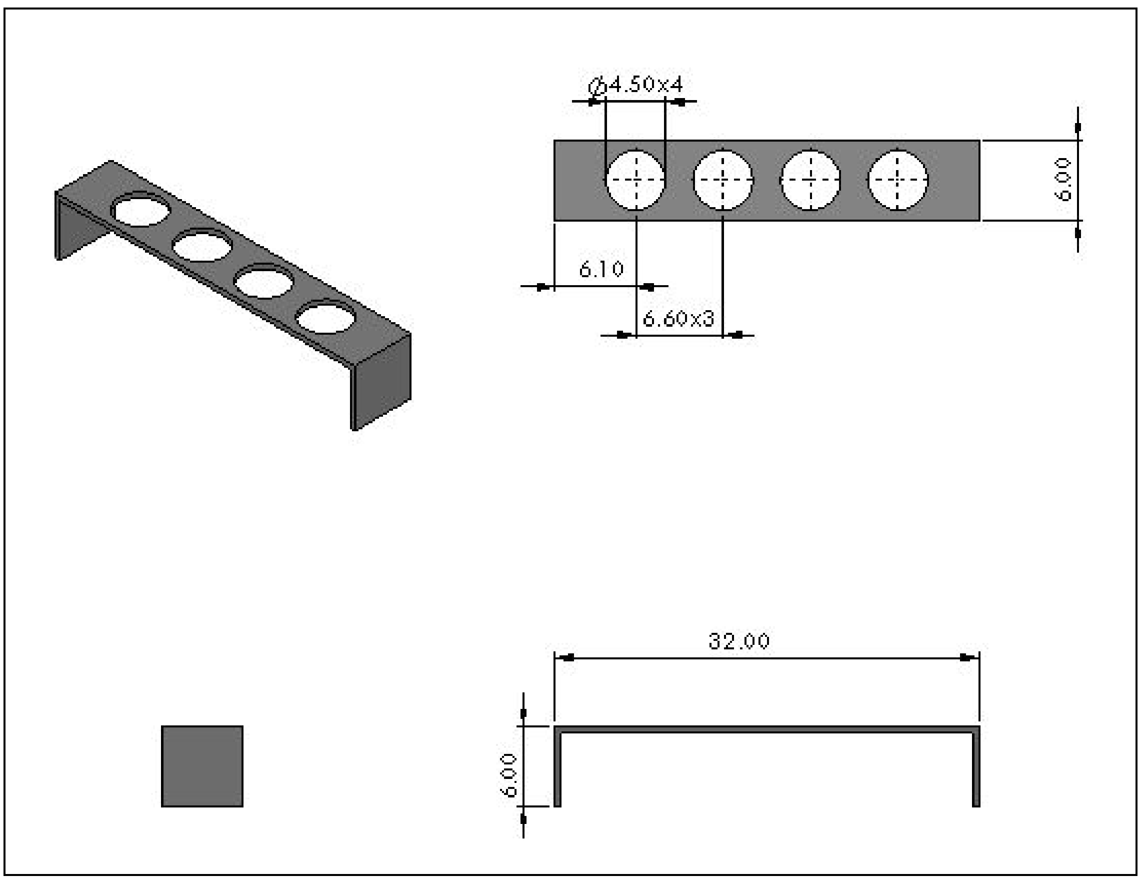

Figure 15: Shelf 1 dimensions (Artist: C. Cordero)

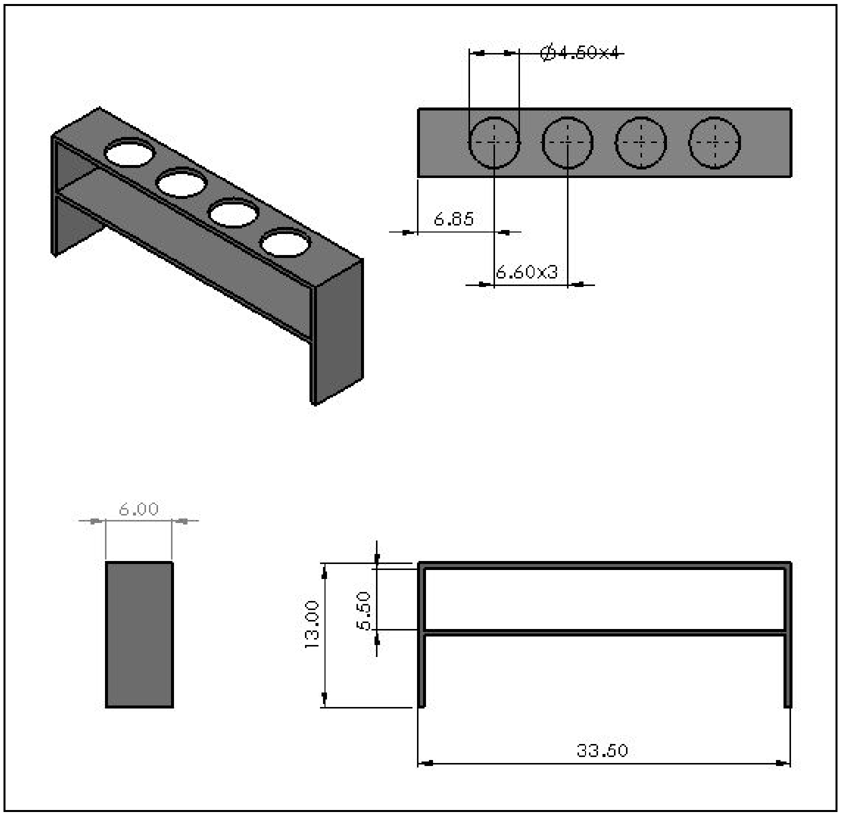

Figure 16: Shelf 2 dimensions (Artist: C. Cordero)

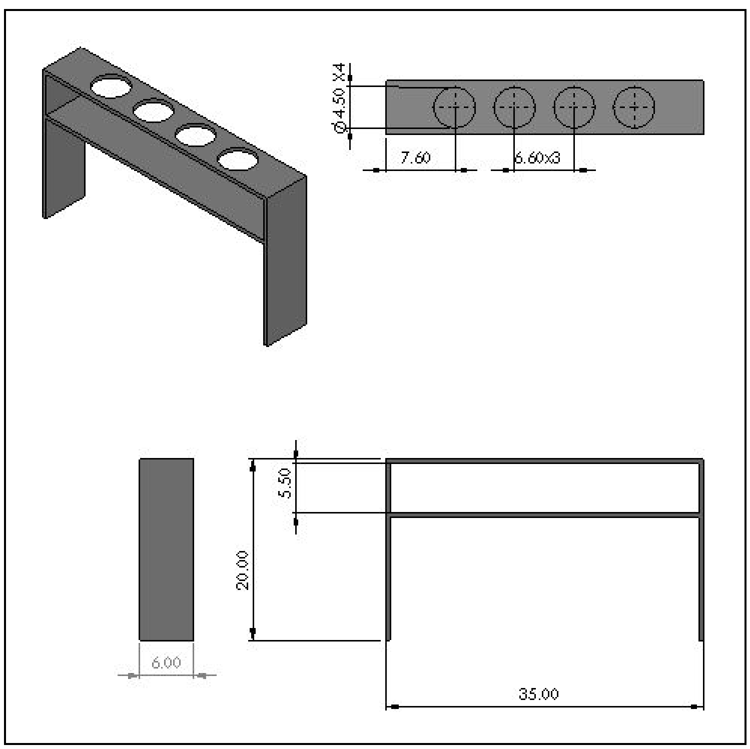

Figure 17: Shelf 3 dimensions (Artist: C. Cordero)

Appendix B: Original Call for Proposals Text

Food Desert Heroes (FDH)* is seeking proposals for novel technological approaches to empower individuals and families living in concentrated urban areas to grow their own supplemental supply of fresh food.

Food deserts are geographic areas where people's access to affordable, healthy food options is restricted or nonexistent due to the distance or absence of mainstream grocery stores.[1] While food deserts still have food, there is an imbalance of food choices, meaning a heavier concentration of processed, packaged foods that are high in salt, fat, sugar and devoid of nutritional value. These "fringe foods" come from fast food restaurants, convenience stores, gas stations, discount bakeries, and liquor stores.[2]

It is estimated that 23.5 million people (7.4% of the total population) across the US live in food deserts.[3] Nearly half of all people in the US living in food deserts are low-income, and are commonly communities of color. Coupled with the fact that healthier foods are typically more expensive than unhealthy foods, healthy food options are often entirely beyond the monetary means of many of these communities. Even if families are receiving food stamps from the USDA's Supplemental Nutrition Assistance Program (SNAP), access to mainstream grocery stores is still restricted. In some areas like Detroit, the vast majority of food stamp retailers are convenience stores, liquor stores, and gas stations.[4]

What we eat is directly correlated to our health. The US spends $150 billion annually to treat diet-related diseases annually. Occurrences of diabetes in the US have tripled over the past decade, and currently ⅓ of all children in the US are obese or overweight.[5] Consequences of long-term constrained access to healthy foods is one of the main reasons that people of color and low-income populations suffer from statistically-higher rates of obesity, type 2 diabetes, cardiovascular disease, and other diet-related conditions as compared to other populations.[1]

This Call for Proposals focuses on the need to empower individuals and families living in concentrated urban areas to grow their own supply of fresh food to supplement the food they may or may not be receiving from other initiatives and organizations as well as that which they purchase.

<u>Solution Requirements</u>

We invite proposals that present compelling solutions for an individual or small family to grow a supplemental supply of fresh food by means of a food-production system that can be implemented in small locations without direct access to ground soil (meaning seeds cannot be sown directly into the ground).

- We will prioritize sustainable, human-centered, and scalable solutions.
- The solution should be designed with a specific stakeholder group in mind, assume implementation in Golden or the surrounding areas.
- The course does not allow the time to grow and harvest crops of vegetables or raise animals to maturity. However, through research, testing, and prototyping, teams should determine the quantity, type, monetary value, and energy value of the food to be produced. **At least 3 types of food must be produced.**
- The system must be self-sustaining to increase ease of use.

- The proposal, while showcasing and quantifying the value and positive social, environmental, and other impacts, must also quantify the negative impacts. All projects involve some degree of risk, cost and time commitment. The final solution must include cost versus benefit analysis, a risk-mitigation plan and an operations and maintenance plan.
- The cost of the working prototype is not to exceed $100 and no dimension of the working prototype may exceed 3 feet. There is no cost limit to the final proposed solution, but the proposal must demonstrate that the solution cost (both initial capital costs and operating costs) is commensurate to the value offered.
- Safety: All prototype testing must be safe to students, and the final solution should be safe to any potential users. Absolutely no animal testing or experimentation, although in situ observations are highly recommended if relevant to your solution.

Out-of Scope for this Call

- Designing a community garden or other large-scale system.
- Non-technical solutions focused on political, social, or economic intervention (for example, nutrition education outreach programs to families).
- Solutions that grow plants for medicinal or recreational purposes.

Submittal

- The final design report must be accompanied by a working prototype. This prototype will likely be a smaller and less-refined version of the final solution. However, the working prototype must demonstrate the key functionality and unique features of the final solution.
- The EPICS in-class Trade Fair presentations are mandatory for all students and will provide teams with the opportunity to demonstrate their final solutions.
- Final solutions will be evaluated on:
    - Creativity and degree of effort put forth into the problem-solving process
    - Value offered by the solution (cost versus benefit)
    - Ease of use, technical feasibility, sustainability, and effectiveness (includes safety)
    - Quality of submissions (sophistication of works-like prototype, consideration of stakeholders' perspectives, depth of report, and degree to which all claims are substantiated).

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**FDH is a fictitious organization.*

Appendix C: Additional Testing and Research Validations

Hydroponic Soda Bottles

The team carried out two additional tests to ensure that the hydroponic soda bottles would function properly. To test if aluminum foil would successfully block enough light to inhibit algae growth, the team constructed two soda bottle systems and wrapped one in aluminum foil. Both bottles were placed in a window for fours days. Figure 18 displays the results of the experiment. The uncovered bottle exhibits extensive algae growth, while the wrapped bottle does not have any visible algae, suggesting that the aluminum foil method does indeed prevent algae from growing.

Figure 18: Unwrapped bottle had significantly more algae growth (Photo by: L. Nield)

Furthermore, the team frequently observed that the top portion of the soda bottle system would often fall into the "reservoir" portion of the bottle. As a result, the team decided to test the stability of the bottles using duct tape, paper clips, and binder clips. Using three soda bottle systems, the team wrapped the top rims of the bottles in duct tape. The team then used two binder clips to hold the top of one of the bottles and two paper clips to hold the top of a second bottle (See Figure 19). They then measured the amount of time before the tops fell into the bottom of the bottle. The results of the experiment can be found in Table 4. It appears that both the binder clips and the paper clips were equally effective in keeping the tops of the bottles stable.

Table 4: Summary of the bottle stability test. This experiment concluded after a week of testing.	
Support Type	**Time the Top Remained Stable**
No extra support	3 days
Paper Clips	Never Fell
Binder Clips	Never Fell

Figure 19: The tops of bottles secured with binder and paper clips (Photo by: L. Nield)

The Science with Style team also used research to validate that the chosen vegetables could successfully grow in a hydroponic soda bottle system. Since greens do the best indoors, especially using the Kratky Method, the team has chosen to grow lettuce, spinach, and peas in the hydroponic soda bottles. According to Joanne Camas, leafy greens grow quickly and do not have the extensive sunlight and nutritional needs that fruiting plants have. For example, the 4-liter Kratky method will grow one bunch of lettuce approximately every 30 days [1]. Lettuce is also a cool weather crop that prefers temperatures between 45°F and 80°F and will thrive in partial shade, making it an ideal indoor plant that does not require an artificial lighting source. Lettuce can also grow in a small space, even a container, so it is compatible with the 2-liter bottle design [2].

Much like lettuce, spinach is also a fast-growing plant that prefers temperatures between 35°F and 75°F and can grow in partial shade. Spinach can also survive temperatures down to 15°F, making it a very adaptable plant in the winter. Hydroponically grown spinach takes approximately 5-1/2 weeks to harvest after the seeds have been sown; thus, the stakeholder will rapidly benefit from the system [3]. Furthermore, snow peas are also a fast-growing crop that thrive in partial shade and are best grown in temperatures below 80°F, again making them ideal crops to be grown in an apartment or house with only a natural light source [4].

Nutrients

Troubleshooting Guide

In order for the Troubleshooting Guide to work effectively, the stakeholder must be able to understand the instructions mean and know what steps to take to mitigate nutrient problems when adding nutrients to the reservoir. After surveying five stakeholders, 90% of the stakeholders accurately diagnosed each plant by stating the the plant needed more nutrients or less. However, after this test it became clear that the Troubleshooting Guide must include images of the actual plants that HydroGro 2.0 produces. From this feedback, the team changed the the images in the Troubleshooting Guide to photos of unhealthy spinach and lettuce.

Another overwhelming response from the stakeholders was that the nutrients system was too complex. Because of this feedback, the team altered the method in which the nutrients are stored. Instead of using a complex system that is hard to understand, the nutrients are stored in a pill container because most elderly people have either seen or used one before.

Time Component of Adding Nutrients

One of the Science with Style's primary objectives when building HydroGro 2.0 was to make the product self sufficient requiring minimal involvement from the stakeholder. Thus, it is important that the stakeholder can accurately diagnose each plant and add the proper amount of nutrients to the reservoir in a relatively short amount of time. The team tested this by providing stakeholders with photos of 12 plants and timing the amount of time it took for them to diagnose each plant. Every stakeholder diagnosed each plant within 5 minutes, well under the team's goal of 15 minutes. From this, the team knows that HydroGro 2.0 does not largely alter the stakeholder's schedule or affect their daily life.

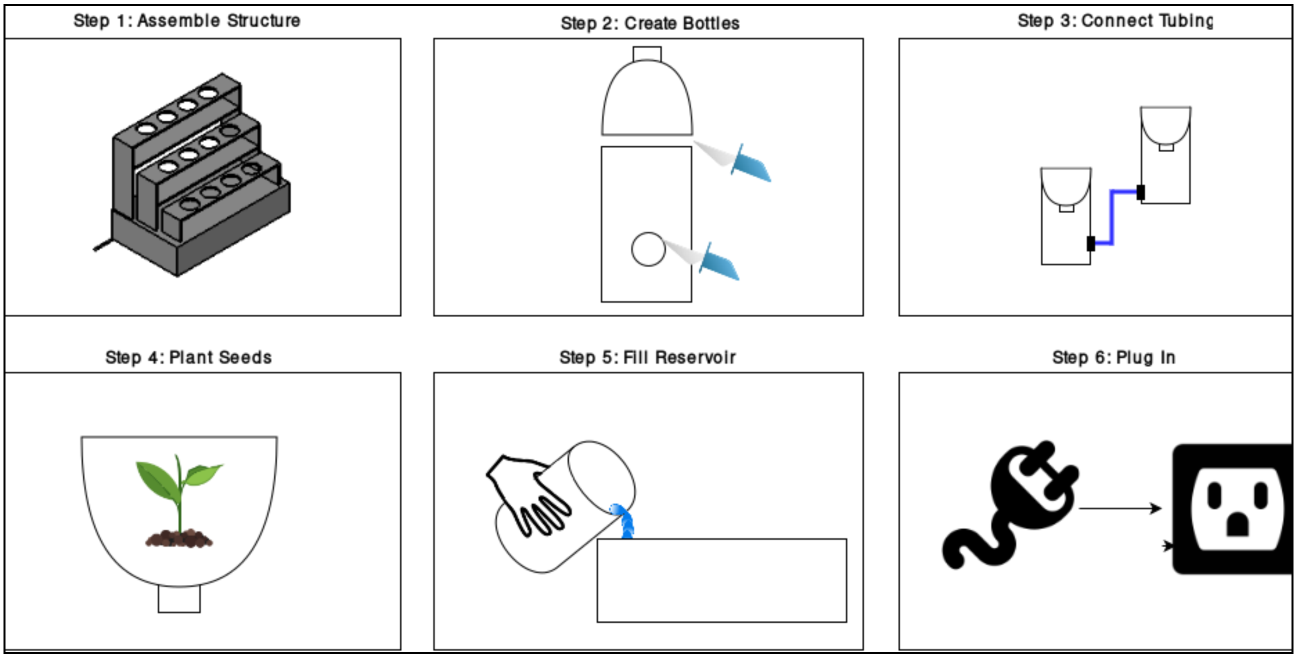
References

1. J. Camas (04 Sept. 2014). *Home Hydroponics* [Online]. Available: http://www.epicurious.com/archive/blogs/editor/2014/09/home-hydroponics-easy-tips-for-growing-fresh-produce-all-year.html. Accessed: Nov. 2, 2016.
2. N. Mattson and C. Peters (2013). *A Recipe for Hydroponic Success* [Online]. Available: http://www.greenhouse.cornell.edu/crops/factsheets/hydroponic-recipes.pdf. Accessed: Nov. 1, 2016.
3. E. Biksa (22 Feb. 2015). *Growing Hydroponic Spinach* [Online]. Available: http://www.grozine.com/2015/02/22/growing-hydroponic-spinach. Accessed: Nov. 1, 2016.
4. The Old Farmer's Almanac (2012). *Peas* [Online]. Available: http://www.almanac.com/plant/peas. Accessed: Nov. 1, 2016.

Appendix D: HydroGro 2.0 Usage Instructions

The following text is a draft of the instructions that will come with HydroGro 2.0. This text is only in English, however, in the final product, a Spanish version will be provided as well.

Setup HydroGro 2.0



1. **Assemble Structure:**
    a. Take the individual components out of the reservoir holder.
    b. Place the three bottle holding racks on top of the reservoir holder.
    c. Place the reservoir inside the reservoir holder.
2. **Create Bottles:** The following must be done for each 2 liter bottle:
    a. Use the bottle construction tool to cut the top off of the bottle.
    b. Use the bottle construction tool to make a hole in the bottle.
    c. Attach the bulkheads to the bottle.
3. **Connect Tubing:**
    a. Place the hydroponic bottles into the bottle holding rack.
    b. Use the pre-cut tubing to connect the pump to the top row of bottles.
    c. Use the pre-cut tubing to connect each row of bottles to the next.
    d. Use the pre-cut tubing to connect the bottom set of bottles back into the reservoir.
4. **Plant Seeds:**
    a. TODO: Figure this out
5. **Fill Reservoir:** Fill the reservoir with tap water.
6. **Plug In:** Plug the pump into the SmartPool Programmable Pump Timer and plug the timer into a standard wall outlet.

Weekly Maintenance

Perform the following maintenance activities once every week.

1. Check the water level in the reservoir. If the water level is below the fill line, refill with water up to the fill line.
2. Check on the plants and determine if the nutrients need to be adjusted. (See Troubleshooting in Appendix D for details.)
3. Add one unit of nutrients

Monthly Maintenance

Perform the following maintenance activities once every month.

1. Empty the reservoir and wash it either in a dishwasher or by hand (the reservoir is dishwasher safe).
2. Clean the pump by taking the intake valve off and rinsing the pump's internal components with tap water.

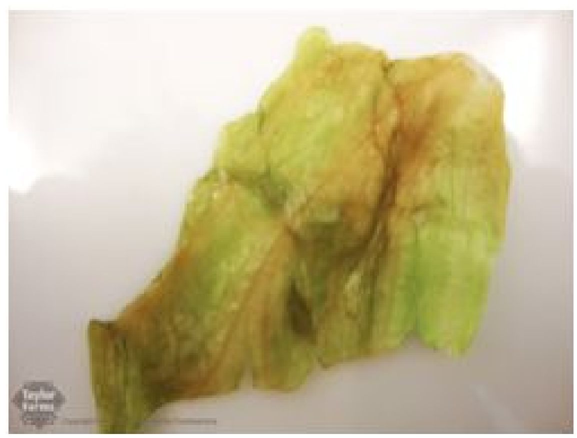
Troubleshooting

Add an extra packet of nutrients if:

- the plant looks tall and skinny
- the plant has little to no leaf growth

Add only half of the nutrients if:

- the leaves have yellow streaks
- the plant is wilting



Appendix E: Decision Matrix

To select the final solution design, the team used a decision-making matrix to evaluate and prioritize the list of options. The team first established a list of criteria, such as the system's sustainability, it's ability to distribute nutrients, and it's viability, and then evaluated each option against those criteria. Table 5 is the decision-making matrix that the team used to choose the final design. The team chose the three highest-scoring options (soda bottle hydroponics. 3-step construction, and automated watering reservoir) to be incorporated into the finished product.

Table 5: Decision-Making Matrix					Key: 1=low, 2=med, 3=high			
Option	Sustainability	Feasibility	Viability (Cost)	Creativity	Safety (risk)	Ease-of-Use	Nutrient Distribution	Total
Soda Bottle Hydroponics	3	3	3	2	3	3	2	**19**
Manual Watering Garden	2	2	2	2	2	2	1	13
Automated Nutrients System	2	1	1.5	3	1.5	3	3	15
3-Step Construction Design	3	3	2.5	2	2.5	3	2	**18**
Automated Watering Reservoir	3	1.5	3	3	1.5	1.5	2	**15.5**
Cascading Watering System	3	1.5	2	2.5	1.5	1	1	12.5

Appendix F: Team Photo and Biographies

Figure 20: Team photo (left to right: Cooper, Cade, Lilli, Lindsey, Sumner)

Cooper Cordero

Cooper is a freshman at Colorado School of Mines. He was born and raised in Littleton, Colorado and went to Arapahoe High School. Cooper is looking to major in Metallurgical and Materials Engineering.

Jonathan Sumner Evans

Jonathan Evans, who goes by Sumner, was born in Phu Tho, Vietnam and was adopted when he was six months old. He has lived in Littleton, Colorado since that time. Sumner was homeschooled and also attended Red Rocks Community College before being accepted to Colorado School of Mines. Sumner is a Junior pursuing a degree in Computer Science with a Minor in Applied Math.

Cade Nash

Cade Nash is from American Fork, Utah, and moved to Colorado Springs, Colorado when he was 2 years old. Cade attended William J Palmer High School, and is now a sophomore looking to major in Electrical Engineering.

Lindsey Nield

Lindsey is from Highlands Ranch, Colorado, and graduated from Thunder Ridge High School. She is currently pursuing a bachelor's degree in Applied Math and Statistics at Colorado School of Mines.

Lilli Peters

Lilli Peters attended Austin High School in Sugar Land, Texas. Now, as a freshman at Mines, she is aspiring to major in Mechanical Engineering.

Signatures

The below-signed parties approve the content of this report and agree that the content meets team quality standards.

Cooper Cordero

Jonathan “Sumner” Evans

Cade Nash

Lindsey Nield

Lillian “Lilli” Peters