Hydroponix - Design Report

Urban Discovery Academy
Project Final Report
December 10, 2017

Aeroponics Tower System

Team Members
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Client
Urban Discovery Academy
Samantha Lee, Third Grade Teacher

University of California, San Diego
ENG 100D, Fall 2017
Brandon Reynante

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Executive Summary

The goal of our project was to create an engaging and interactive educational experience for the students of Samantha Lee's third grade class at the Urban Discovery Academy. This educational experience consists of a aeroponics tower, lesson plan, and manual. All of these components are meant to be used together by Samantha and her students in order to learn more about the concepts involved in hydroponics and aeroponics as well as introduce more greenery into the classroom setting.

Our partner organization is Urban Discovery Academy (UDA). UDA is a charter school for students in TK through 8th grade located in downtown San Diego. It strives to create a hands-on learning environment where students are encouraged to explore a variety of subjects and get involved in the surrounding community.

Samantha Lee is a third grade teacher at UDA who wanted to provide an interactive project for her students. One of the main motivations behind this project was to introduce more greenery into the classroom. The area surrounding UDA is not as beautiful or conducive to learning as Samantha would like. For this reason, she expressed the need to introduce greenery into the classroom in order to create a positive learning environment for her students.

From interviewing Samantha and conducting observations in the classroom, we were able to identify a few core needs of our stakeholders. Due to the lack of available space in the classroom, there is a need for a structure that does not take up a lot of space. In order to create a project that is aligned with UDA's mission statement and goals, there is a need for a solution that actively engages students and encourages their participation in the creation and maintenance of the structure. Since Samantha's primary responsibility is to teach her students, responsibilities surrounding maintaining the structure could be easily distributed amongst the kids in order to give them a sense of ownership over the project and also relieve Samantha of some of the necessary tasks. Lastly, while Samantha did express that UDA would be able to provide a budget for this project, she did mention that the cost of the solution should be reasonable.

We took these needs and insights into account and developed design requirements that constrained aspects of our solution. Some of these requirements include: the solution must be economic, functional, durable, and socio-political. Since UDA would most likely paying for the expenses of the project, we did not want to create a solution that was too expensive. The solution should be functional meaning that it does not require excessive time to both install and maintain. In order to function in an active classroom, the solution should be durable meaning that it can withstand daily interaction with young children and will last for the timeframe that students will be in school. Lastly, to satisfy the socio-political requirement, the solution should provide an educational and engaging experience for the students.

In order to evaluate our solution against these requirements, we created a Pugh chart which helped us compare how different concepts performed in each of the categories.

Our final design strives to satisfy all of the design requirements. Through our interviews, we found that the students expressed a big interest in hands-on activities and interactive projects as a way to learn. The aeroponics tower coupled with the lesson plan and manual seeks to provide students with the ability to learn about aeroponics through experience while still providing a compact way to introduce more greenery into the classroom environment.

1. Project Management

1.1 Motivation & Goals

Samantha Lee, a third grade teacher and major stakeholder in this project, would like to create a hydroponics system because the Urban Discovery Academy (UDA) doesn't have many green spaces. Samantha is therefore teaming up with Hydroponix to create a greener classroom environment while also exposing the students to engineering and design principles through the shared development of a hydroponics system in their classroom. She believes that this will be beneficial for her students' development and an excellent complement to their STEAM education. We plan on making this project very interactive and hands-on for the students in addition to incorporating learning about the basic principles of science, engineering, and design. We want this whole experience to complement and support the STEAM lessons they are currently learning in school. Since the students already have some past experiences with hammers, nails, and working in teams, we want them to help us build the garden and customize it to their liking. Samantha is giving us a lot of freedom in this project, so we can modify it along the way if necessary.

1.2 Approach & Schedule

Different stages of the project will incorporate various types of information-gathering, stakeholder-engagement, design, and planning methods. We will be mainly utilizing the human-centered design process in this project: Empathize, Define, Input & Feedback, Ideate, Input & Feedback, Prototype, Input & Feedback, and finally Test.

Stakeholder research will involve a combination of one-on-one interviews (teachers), small focus groups (students), and survey techniques (parents) that will allow for contextualized information gathering and empathy with the various stakeholders. Further secondary research of publicly accessible online resources (eg. UDA website) will allow the team to gather relevant background information on the school. Stakeholder engagement will be a continuous activity that will involve the solicitation of feedback from key stakeholders via in-person, email, and video/audio call conversations, in order to have stakeholder participation throughout every step of the initiative, and develop shared project ownership. The design process will also involve thorough analysis of related historical projects, including similar projects (composting at UDA) that our stakeholders themselves, or similar groups have taken part in. The design and construction of the unit will (likely) be divided into various parts of the hydroponics system, with dedicated subgroups working with key stakeholders to design and build each part which will be combined into one, integrated final product. Parental consent will be obtained for all project related activities in the form of a signature form. In order to develop shared ownership of the project with our partner organization we will be dividing our team into smaller subgroups that will be responsible for coordinating with each other as well as the partner organization. These groups will maintain constant and effective communication with the partner organization to ensure that this project is developed according to their needs. While meeting with the stakeholders, each subgroup will perform a variety of tasks to gain insight into their lives, needs, and goals for this project. This will be accomplished by interviewing the students, parents, teacher, and school board that are connected to the UDA Indoor Hydroponics project. The team as a whole will also be in contact with the primary stakeholder, Samantha Lee, throughout each phase of the project in order to develop and maintain shared ownership of the project between team members and the stakeholders.

User research and information gathering
To create empathy we will immerse ourselves into the daily life of our stakeholders as much as we could. We will do this by designing interview questions that will evoke empathy and an understanding of their experiences in the community, by observing our stakeholders and recording both qualitative and quantitative data , by researching any socio-economic factors impacting the school and the community, and by spending time in our users world (inside the school itself).

Design definition and ideation
Our team will try to pinpoint the stakeholders' immediate needs, and then will try to understand the underlying problems that may be causing those needs. This will be done by analyzing the data that we collect during the information gathering phase, and will decide during a team meeting what might be best to focus on as a design solution. We will ultimately define the problem by creating a question that we will answer through our design process. After choosing which ideas work best, with the help and feedback for the stakeholders, we will focus our efforts on creating a model/prototype of those ideas.

Prototyping
For the prototyping phase of the project, we will separate into different subgroups each focusing on designing a prototype. The different subgroups must be diverse in terms of skills and background so that the process can be smoother and efficient. Each prototype must be made as cheaply as possible and must be able to highlight and focus on a certain need that our end design solution must have. After the team has created the different prototypes, a final prototype will be designed by the entire team as a whole, and will possess the best qualities that the other prototypes had.

Input and Feedback
Throughout the entire information gathering, design definition and ideation, and prototyping phases, our team will communicate with all of our stakeholders including: the students, the teacher(s), and parents. We will present on our progress, how our work fits the user needs that we gathered, and will obtain input and feedback to better tailor our project for their needs. This will be in the form of iterative, periodic interviews and focus groups. After developing an idea and prototype model with the help of our stakeholders, we will request approval for the design and budget from Samantha Lee, and make any necessary tweaks if need be.

Construction and Testing
During the construction and testing phase, we will take certain parts of our prototype and will test these parts around the UDA campus. Each piece of the prototype will help us gain insight on whether each part of our prototype is going to work. We will observe and take photographs and videos of our users during testing, as well as throughout the ongoing stakeholder engagement

process. We will also test the model as a whole for any issues, and make adjustments as necessary.

Training

The team will complete and distribute a comprehensive user manual for the design that was constructed, and provide the necessary training in order to ensure adequate maintenance and upkeep of the final product. Since the users will be engaged in the design and construction of the project at large, this will likely be in the form of a recap and final feedback session.

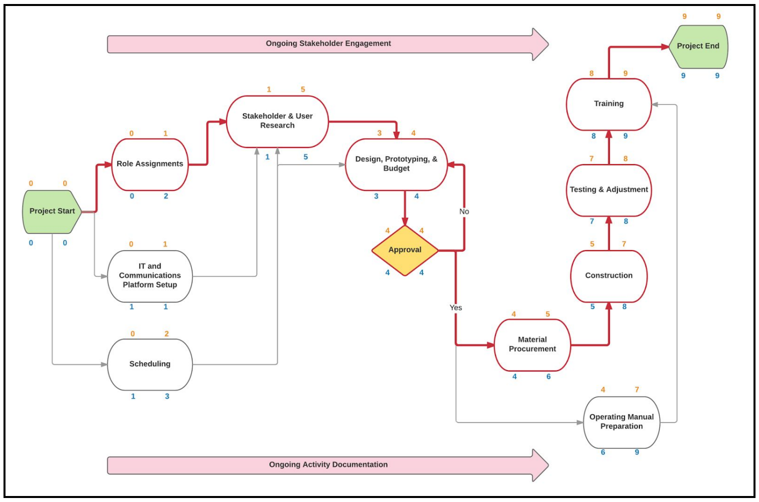


Figure 1: Network Diagram and Project Critical Path (link for clearer image: http://bit.ly/2gww3GE)

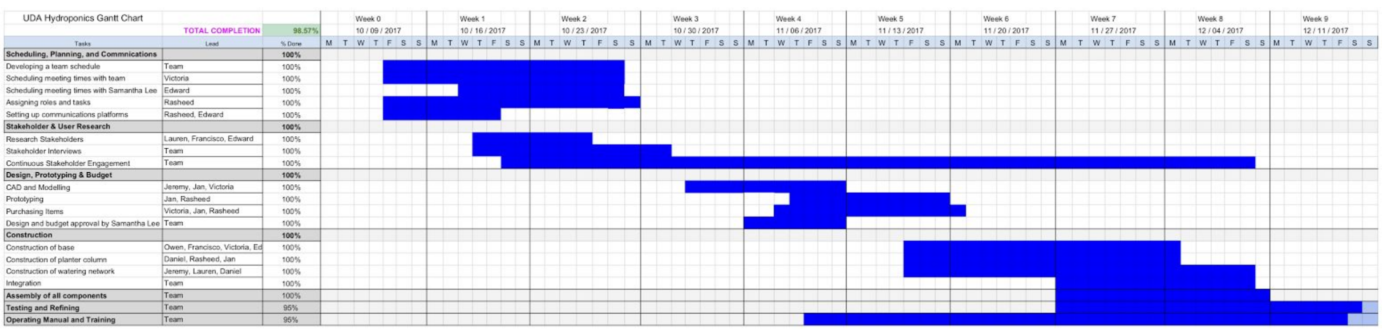
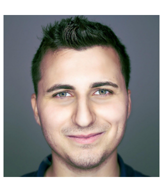


Figure 2: Gantt Chart with expected timeline (link for a clearer image: http://bit.ly/2xYN9TO)

1.3 Team Member Bios

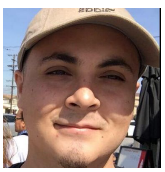


Rasheed I. Al Kotob **Email**: ralkotob@ucsd.edu **Phone**:(831) 224-7017

Rasheed Al Kotob is a fifth-year undergraduate in the Department of NanoEngineering at the UC San Diego Jacobs School of Engineering. Rasheed is passionate about community service work and finding solutions to real world problems. He is excited to be working with the Urban Discovery Academy (UDA) and the Global TIES program to help create an exciting, engaging, and informative hydroponics project experience for the students at UDA. As the Hydroponix team leader, Rasheed oversees the team's progress and communicates consistently and openly with team members to ensure they have the support, resources, and time they need to fulfill their tasks successfully.

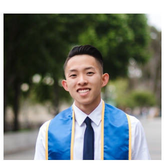
Owen Chen **Email:** onchen@ucsd.edu **Phone:**(909) 979-7028
As a General Team Member, Owen is responsible for communicating effectively with both his fellow team members and the stakeholders of the project in order to ensure that the goals of the UDA Indoor Hydroponix System project are met. Owen is currently a third year student studying Chemical Engineering, and is familiar with thermodynamics and basic reactor design. He is also a member of UC San Diego AIChE's Wave Power Conversion project.

Victoria Tam **Email:** vmtam21@gmail.com **Phone:** (626) 236 - 3150
Victoria is currently an undergraduate third year Bioengineering: Biotechnology major at UCSD and is interested in positively impacting the food industry with genetic engineering. In the UDA Indoor Hydroponix System Team, she is responsible for booking rooms for team and meetings, and being an active communicator with the stakeholders and the team.

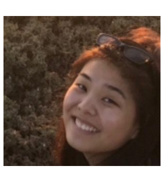


Francisco Ochoa **Email**: fochoa@ucsd.edu **Phone**: (323) 559-6893
Francisco is a General Team Member of the UDA Indoor Hydroponix System team. As a General Team Member I am responsible for: being involved and supportive at every phase of the project, attending all scheduled team events, completing all assigned tasks in an efficient and timely manner, and adding suggestions and innovative ideas.

Jan Eric De Castro **Email**: jedecast@ucsd.edu **Phone**: (707) 812-5737
Jan is the Historian of the UDA Indoor Hydroponix System team. His general role will be but is not limited to documenting any group activity through photos and video and upload any type of media to the team's google drive. His field of expertise lies in design, thus he has experience in the product design and industrial design field. He also has past experience with hydroponic/aeroponic/aquaponic gardens.

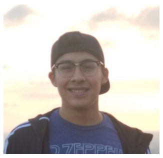


Edward Lin **Email:** edlin@ucsd.edu **Phone:** (909) 646-0843
Edward is currently a fifth-year undergraduate studying Mechanical Engineering at the Jacobs School of Engineering at UC San Diego. He serves as the main point of contact between the team and its partners at the Urban Discovery Academy. He will coordinate meeting times with the stakeholders and ensure that everyone involved is up to date with pertinent information as the project progresses.



Lauren Gong **Email:** lmgong@ucsd.edu **Phone:** (650) 833-8996
Lauren is a fourth year studying Cognitive Science with a specialization in Human Computer Interaction. She is familiar with user research and the process of human centered design. As a General Team Member for the UDA Indoor Hydroponix

Systems team, her responsibilities include being proactive in team meetings and communicating with stakeholders throughout the project.



Daniel Vazquez **Email:** d7vazque@uscd.edu **Phone:** (626) 347 - 0470
Daniel is a second year physics major with a specialization in computational physics. His hobbies include playing guitar and soccer. He thrives in team oriented projects and is excited to work on the UDA Indoor Hydroponix Systems team. His roles include but are not limited to communicating with stakeholders and creating a user research plan.

Jeremy Borja **Email:** borja.jeremy@gmail.com **Phone:** (619) 948-7987
Jeremy is a third year undergraduate student at UC San Diego majoring in Cognitive Science with a specialization in Human-Computer Interaction and Design. As a team member of the UDA Indoor Hydroponix Systems team, he will assist in the development of the project by providing input and feedback through communication with his team as well as promptly completing tasks on time.

1.4 Stakeholder Analysis

Samantha Lee: Samantha is a third grade teacher at the Urban Discovery Academy and is our main partner for this project. Based on how involved she will be on this project, we have decided to place her on the top right portion (high interest and high power) of the matrix. It is important that we consistently keep her updated and regularly consult with her on major decisions.

Students: The students we will be partnering with are third graders attending the Urban Discovery Academy. This project will be a collaborative effort between our UCSD team along with the students. As a result, the students will play a large role in the entire process. On the matrix, we placed them in the top right corner (high interest along with high power). The students' input and critique is vital for the success of our project. We will seek to regularly consult with them throughout the duration of the project.

Professor Brandon Reynante: Professor Reynante is the instructor who oversees the ENG100D course. As the instructor he has a considerable level of power over the project. His expertise in human centered design and experience working with Global TIES, as well as his interest in seeing the project succeed makes him a valuable ally. We will engage with him often for advice, as well as stay accountable to all project report timelines he has set throughout the quarter.

Parents: The parents will undoubtedly be interested in the project but will not be directly involved. As a result, we have chosen to place them in the middle of the matrix (medium interest along with medium power). We will reach out to them for approval to work with their children.

Board of Trustees: The Board of Trustees are in charge of approving all major educational and operational policies and decisions at the Urban Discovery Academy.

Based on this, we have decided to place them in the top left corner of the matrix (high power but lower interest in the project because they will not be directly involved). We will ensure that we are complying with all current UDA rules and policies.

Other Teachers: For this project, we will be partnering with only one class of students. Other teachers may take interest in what be are doing but will not be directly involved. As a result, we have chosen to place them in the lower two quadrants of the matrix (medium interest and low power). Figure 3: Stakeholder Analysis Matrix

UCSD: Throughout the duration of this project, we will be required to regularly update our ENG 100D professor and TA on our progress. Our work on this project is a direct reflection of UCSD, so the university may have some interest in this program. This is why it was placed in between the bottom two quadrants (medium interest, low power.

1.5 User Research Plan

We plan to interview three main types of participants when working on this project: Samantha Lee (primary stakeholder and user) (initial interview complete), students (end users), and parents. In the initial stages of our user research, we plan to use interviews as an opportunity to do some initial needfinding in order to understand the project's scope as well as the expectations of each participant group. We have a few questions for students but mostly want to create something that is fun and interactive for them. We feel that it would be most effective to do user observations for the students in order to gain a better understanding of the context of the classroom. Furthermore, we are conducting online research about UDA in order to learn more about the school's background, its policies, and its community. As the quarter progresses, these participants will be valuable sources of feedback for any future prototypes or design solutions that we will want to test. We plan to visit on-site in two groups, alternating each week in order to continue to talk more with stakeholders and receive feedback throughout the process.

Interview Questions

Samantha Lee

1. Can you tell us more about yourself (background and education) and why you're teaching in UDA?
2. Motivation behind building a hydroponic garden?
    a. How does this project align with your curriculum (if at all)?
3. What is your relationship with the board (ask for possible stakeholders)?
4. What do you want your students to learn? How will the students interact with the garden (how involved)?
5. Can you talk about an average day in your classroom?
6. Ask about a schedule where we can observe and interview students and possible timeline
    a. Assign different times for parts of the group to observe
7. What would you like as the final product/you envision this garden will look like and do?
8. Any possible constraints in this project? Space? Ethical?
9. How would you like your students to engage during this project?

10. Do you have a dedicated budget to this project and what is it?

Students

1. What is your favorite subject? What's the coolest thing you've learned so far? Why?
2. Does this project sound interesting/fun to you? Why?
3. Have you ever worked on anything like this before?
4. What do you think you will learn from working on a hydroponics garden? What do you want to learn from this project?

Observation goals

1. Finding their learning style
2. Understanding classroom dynamics/organization
3. Understanding demographics of classroom

2. Problem Definition

2.1 Problem Statement

Samantha Lee and her students need a **low-maintenance, affordable and interactive educational experience** relating to **plant** sciences, that complements their curricular science education, and modifies their sterile **urban classroom into a greener space**.

2.2 Background & Context

The purpose of Urban Discovery Academy is to provide students in TK through 8th grade with design-thinking and project-based learning. UDA is a free-public charter school with staff who hope to produce well rounded individuals, exposing them not only to educational studies but also to sports and the arts. Along with these qualities, they would like to engage their students in the community and allow them to be more socially receptive and responsible.

UDA's philosophy strives to provide a hands-on and interactive learning experience that extends the walls of the school and encourages students to become active participants in the community. The curriculum aims to integrate real-world applications and introduces concepts in science, engineering, and business. Ultimately Samantha wants to provide a positive learning experience in a beautiful space for her students. However since UDA is located in downtown, she mentioned that the area surrounding the school is not as pleasant and conducive to learning for the students as she hoped. Furthermore, there's a lack of greenery for the kids to enjoy and learn from. In order to provide a more pleasant learning experience, she wants to be able to incorporate some greenery in her classroom in a way that involves them in the process. Our Hydroponics system will be the means for the student to learn botany and the future of more sustainable farming. There also exists space constraints within her classroom that make incorporating greenery and plants a somewhat difficult task.

This school emerged due to the intersection of two concepts: San Diego regional planners wanted more families to live and work in downtown San Diego and national educational leaders wanted to spread and integrate the concept of STEAM (it's STEM but added "A" for arts) into local schools across the nation. Although the school was recently built, there were past struggles with its construction due to the lack of financing during the economic recession of 2008 and no political support. This school only became a reality due to two main advantages: the school had the backing of civic and business leaders who believed that a quality k-8 school will be an important factor in attracting young professionals in the future and was supported by benefactors who believed that education was a wise investment (e.g. Jeff Silberman, Charleton Management's president, donated $125,000 to help fund its constructions).

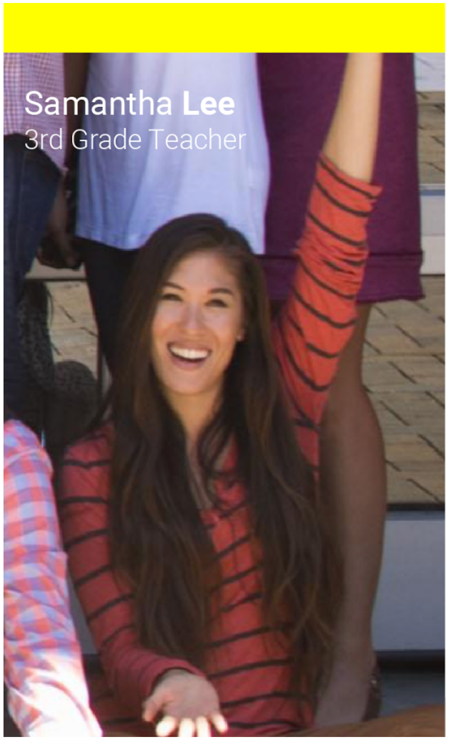
Figure 4: Photos of the surrounding UDA.

There are a lot of online resources available to help with this design challenge. Many hydroponics systems or plant based systems in general have been made, so any questions we need answered or challenges we might face could be found online. In regards to labor, we have 9 people on our team to help build the project. Since Samantha Lee wants a more hands-on project for her students and the fact that UDA is a project-based learning charter school, provides us with the help of students to complete this project. In terms of materials to use for this project, most items will be bought from a hardware store, like Home Depot and subsidized by UDA. However, one thing that leverages the cost of this design challenge is the soil. Since hydroponics systems need soil, it we most likely be used from another teacher at UDA's composting project. This combines the two projects and gives more opportunity to learn more about plant life, different planting systems, and the importance of reusing resources.

We learned through our interview with Samantha that one of colleagues worked with a similar program which resulted in the development of a compost project. This project was really successful in engaging students in understanding the process of composting and its benefits. The success of the project later sparked an idea to create some sort of system where students could continue composting and learn about the process of creating a business by selling the compost they've made. This would make the project not only ecologically sustainable but socio-culturally sustainable as well since it is providing students opportunities that align with UDA's mission to inspire them to become innovators and contributors to the community.

2.3 User Profile(s)

Persona 1: Samantha Lee



Tasks

Samantha's responsibilities include supervising her students, creating lesson plans that follows Common core standards yet als engages the her class, collaborate with other teachers and administrators, and liasing with parents to ensure the students have continious support.

Gain

Having new faces to work with students will be exciting and rewarding for them. More greenery in the classroom would be a nice change to the classroom and offer an educational experience.

Pain

Students sometimes difficult to manage. Location of classroom in East Village provides students with little greenery

Feelings

Due to past partnership with Global Ties, she is very excited about the prospect of working with the Hydroponics team too develop an engaging and enjoyable educational science experience for her students. Having had previous success with the program, she is giving the team a considerable amount of freedom.

Influences

As an UCSD alumni, Samantha's familiarity with the school and the program contributes to her level of trust. Her work is influenced by student behavior, parental concerns, state and federal policies, school budget, and the existing classroom space, layout, and materials provided. Cultural influences such as Navy Background may influence her stance on behavioral expectations.

Figure 5: Empathy map for Samantha Lee - a third-grade teacher at UDA

Samantha is a 27 year-old 3rd grade teacher at UDA who graduated from UCSD as an undergraduate majoring in Urban Studies. It is currently her 2nd year teaching at UDA. She really cares about her students and likes making experiences for her students to remember. She doesn't know much about hydroponics or botany, so she she's giving the team the freedom to choose the direction to go with the project. She believes that the connection with UCSD Global TIES and the program is amazing and will be an excellent supplement to her educational curriculum. Having grown up in a Navy family, she has travelled to many places and enjoys bringing her experience and unique perspective to her work.

Persona 2: James

Tasks

James is a student at UDA. He is responsible for getting to school on time (8:00 am) every day. Every night, he makes sure he finishes all of his homework. During class, he does his best to partcipate in class and likes to engage with his friends. Lastly, he is also responsible for tidying up.

Gain

Having a hands-on experience would be very memorable and education for James. Moreover, learning from older stuents and working alongside his classmates will be a fun new way to lear about science.

Pain

James can sometimes feel bored or distracted in class and may lose interest in some subjects. He likes going outside but doesn't have much space to do so.

Feelings

James is often exposed to many different areas of science and basic engineering principles. He is very fascinated by different areas of science including space and biology. James is very excited to interact with and learn from college students who have more experience they can share. He sees them as superheroes, in a sense.

Influences

James grew up in San Diego and was able to be selected via lottery to attend UDA. His parents take great interest in his academic success and often push him to do his best in class and extracurriculars. His parents keep in contact with Miss Lee in order to make sure that their son is getting the support he needs and performing to the best of his abilities. He enjoys playing with his friends during lunch and working with them in class.

Figure 6: Empathy map for James - a third-grade student at UDA

James is a nine-year old third grade student at Urban Discovery Academy. James grew up in San Diego, and was able to be selected via lottery to attend the school. He enjoys playing with his friends during lunch and working with them in class. His favorite subject is science, and likes seeing cool demonstrations of different scientific phenomena presented by his teacher Samantha. He sees older students, especially college students, as somewhat of superheroes, who can be a very useful source of knowledge, insight and wisdom for him. He is excited to work with them alongside his classmates to build something new and exciting.

2.4 Needs & Insights

Needs:

- **Educational Supplement**
  - The content of the project must be **relevant to Samantha's educational materials**, such as biology, chemistry, etc.
  - The project itself must **not interfere with the student's attention** to other classroom tasks/studies
  - The educational experience will focus on **the creation of a green space** in an effort to supplement education on the subject of ecological sustainability
- **Interactive Science experience**
  - The content of the project must address topics that the students will be learning about in class and teach students about **more sustainable farming methods**

    - The majority of the experience must be **maintainable and customizable** by the students
- **Easily maintainable**
    - The installation must be able to be **easily cleaned and maintained by Samantha** and the **third grade students**
    - Parts used must be readily accessible if they need to be replaced
    - Maintenance directions must be **clear and easily understandable** by all users
- **Affordable**
    - Parts and materials used for the installation must be **affordable**
    - Parts and materials used must be able to be purchased locally
- **Aesthetically appropriate**
    - The appearance of the project must **work with the aesthetics of the classroom**
    - The appearance **must include greenery**

Insights:

- **Social-cultural sustainability**
    - Using the students for maintaining the project is key to having the solution thrive after we are gone
- **Source materials from the classroom**
    - Students and Samantha can utilize **water as a resource** to continually fill the system, **cups as pots**, and the **compost** to plant the plants when they mature.
- **Utilize students in maintaining the project**
    - Students can constantly maintain the system to make sure that it it is functioning properly and all the resources needed is available
- **Barriers**
    - The students will only have a limited amount of time each week to interact with the system
    - The solution will not be effective it it does not supplement Samantha's educational materials
- **Causes**
    - **Lack of green space** at the Urban Discovery Academy
    - Creating an educational system would give students hands-on experience with agricultural methods
- **Broad Implications**
    - The system will be designed with reusability in mind, allowing future classes at UDA to use the system if it is successful

2.5 Design Requirements

Table 1: *Chart of design requirements.*

Category	Requirements
Cost	• Cost must be less than $150 because we have a limited budget and do not want to put financial burden on Samantha

Functional	● Functional: installation should not exceed 1 hour because more than than would be too complex for students/teacher ● Functional maintenance should not take more than 15 minutes per week because of Samantha and the children's busy schedule
Durability	● Durability: must be able to withstand interaction with students because it will be a safety issue ● Durability must last for at least the duration of the school year with proper maintenance for full educational experience
Flexibility	● Flexibility: must able to be moved around the classroom or to another classroom because Samantha often reorganizes position of furniture around classroom. Weight should be less than 20 lbs and size less than 3 ft x 3 ft x 3 ft
Technical	● Technical: installation must include one section per student ● Technical ability to see growth within each section in order
Efficiency	● Efficiency: should be able to produce a plant of some type by the end of the school year
Socio-Political Design	● Socio-Political Design: must stimulate student interest and engagement in order to effectively teach the student

3. Concept Generation

3.1 Analogous Solutions Analysis

Existing Hydroponic Techniques

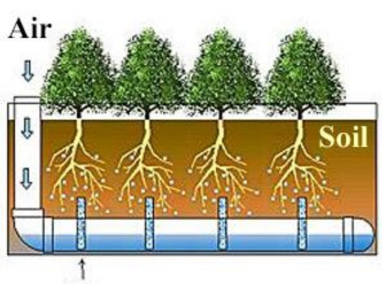


Figure 7: Diagram of Wick System

Wick Systems
Wick systems are the most basic of the six established hydroponic systems. In this type of system, a plant is placed in a growing medium that transports water and nutrients, which are transported to the plant's roots via capillary action through a wicking material such as rope or felt.
Advantages: This is passive hydroponics, a type of system does not require air or water pumps. It is inexpensive, does not require high maintenance, and works well for smaller plants.
Disadvantages: It does not work well for larger plants and relies upon wicking, which makes this type of system less feasible for larger plants that require more water and nutrients.

Deep Water Culture

Deep Water Culture (DWC) systems are another inexpensive hydroponics option where plants are suspended in a growing medium so that their roots are submerged in a reservoir containing water and nutrients. A form of aeration, such as an air pump, is typically implemented in the reservoir to prevent drowning of the plants.

Advantages: This system circulates nutrients, in turn reducing waste. It is inexpensive, is not high maintenance and it works well for smaller plants.

Disadvantages: However, it does not work well with plants that have a long growth period and it does not work for larger plants. The aeration requires a constant power source.

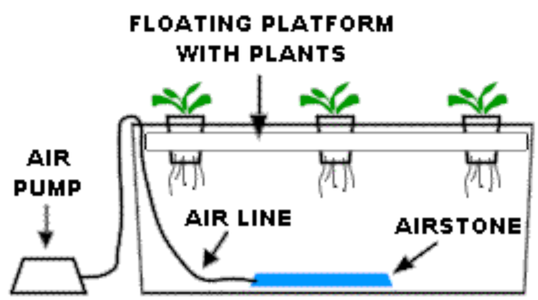


Figure 8: Diagram of Deep Water Culture.

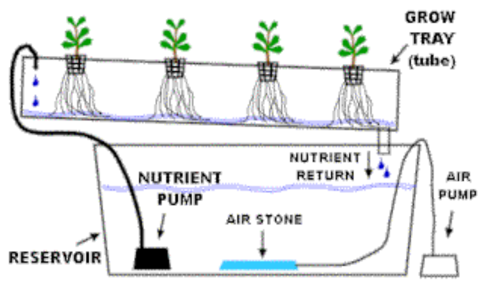


Figure 9: Diagram of Nutrient Film Technique.

Nutrient Film Technique

In Nutrient Film Technique (NFT) systems, plants are suspended in a growing medium so that their roots are partially submerged in a flowing stream of water and nutrients. The entire system is slightly tilted to take advantage of the force of gravity in moving the nutrient stream. The plants are able to absorb more oxygen than in a DWC system, allowing for faster growth.

Advantages: Nutrients are circulated, which reduces waste. Not as much growth medium is required, so there is a higher plant growth rate.

Disadvantages: This technique does have a higher material cost. The water pump for recirculation requires a constant power source and it is heavily dependent upon flowing nutrient stream. Therefore, power outages would result in plant death. Plant roots need to be maintained to ensure ease of nutrient flow.

Aeroponics

Aeroponics is another existing form of hydroponics. This form of hydroponics ensures that the roots growing from the plant are exposed to as much oxygen as as possible. The plants are typically hung in mid air and are housed in baskets, which include foam plugs that compress around the plant stem. The roots are then hung down inside the growing chamber and are then sprayed with nutrient solutions from misters in regular, short intervals.The ultimate goal of this solution is to maximize moisture, nutrients and oxygen uptake from the plants. To build this type of system you need: a container that serves as the reservoir, a submersible fountain

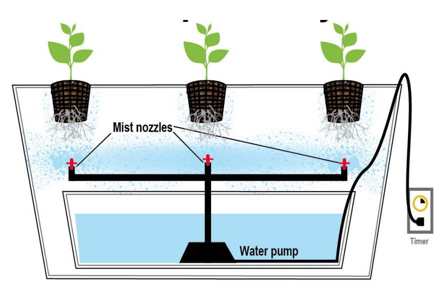


Figure 10: Diagram of Aeroponics.

pump, tubing to distribute water from the reservoir to the mister heads, an enclosed growing chamber for the roots, mister/sprinkler heads, water tight container, tubing to return excess water to reservoir, and a timer to turn the pump on and off. This method is most efficient for growing tomatoes, tomatillos, eggplants, strawberries, watermelons, leafy greens, and various herbs.
Advantages: The roots are exposed to more oxygen. There is no growing media, but the plants still grow rapidly. It is perfect for home growers because it uses less water. Harvesting is also easier with this method.
Disadvantages: It is expensive to build and the misters can get clogged. Also, the roots much more susceptible to drying out.

Drip Systems

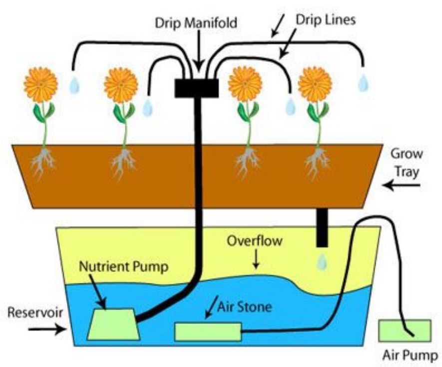


Figure 11: Diagram of Drip System.

A drip system is a type of hydroponic systems that is used both at home and by agricultural industries alike. In this system, the main goal is to drip nutrient rich solutions onto plant roots keeping them moist. It works is by pumping water from a reservoir to the top of a growing media. At this point, the system drops water through tubing onto the plant roots and growing media. To build such a system, you will need a container for the plants could grow in, another container that serves as a reservoir, a submersible fountain pump, a timer to turn the pump on and off, tubing to run water from the reservoir to the plants, tubing for the excess solution, and a growing media. This method is most efficient for growing tomatoes, cucumbers, and herbs.
Advantages: There are only a few parts to build, so there can be a high level control over watering. It will be less likely to break. It is also affordable.
Disadvantages: This technique could be too large scale for a small garden. There is also fluctuating pH and nutrient levels.

3.2 Concepts

Hydroponics Tower

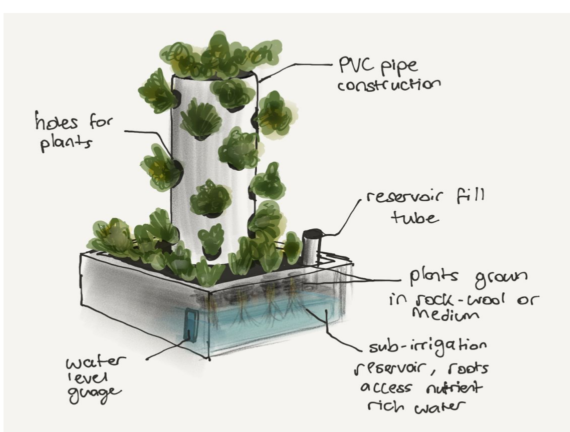


Figure 12: Hydroponics System.

Tagline: This is a vertical space dominant hydroponics system that will allow students to interact with the plants at the base of the device and vertically along the PVC pipe.
Core need: Samantha’s classroom is limited in space. This vertical tower design addresses the space constraint while still being accessible by students and provides a source of greenery for the classroom.
Strengths: This design is space efficient by not taking too much of the counter space while still taking advantage of the vertical space

available. The water gauge and clear plastic used for the reservoir make it easy for Samantha and the students to monitor the water level. Other than monitoring the water level, this tower design would not require a lot of extra work. Additionally, this design requires relatively simple materials that are easy to find which would keep the cost low.
Weaknesses: While this design makes efficient use of the counter space, it would be significantly taller than the other concepts since it would be placed on a counter. The tower might be more difficult for students to reach if they want to look at the plants. Additionally, the reservoir could contribute a lot of weight to the overall design which would make it heavy and difficult to move if needed.

Zig-Zag Hydroponics System

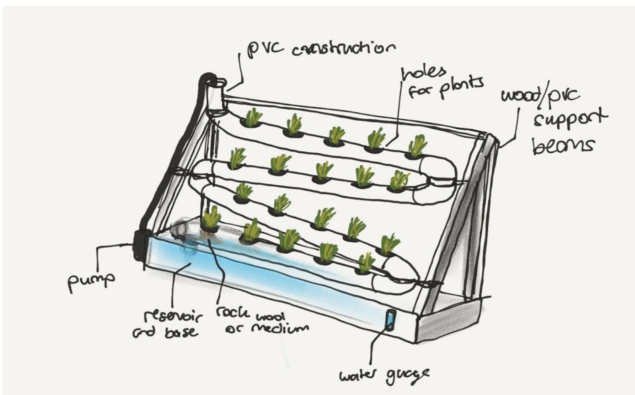


Figure 13: Zig-Zag Hydroponics System

Tagline: A space efficient, interactive hydroponics system that utilizes a zig-zag structure to enhance water flow throughout the system.
Core need: Samantha's need for an interactive project for her students can be easily obtained through this design. The height of this structure is easily accessible to the students and allows them to water each of the plants. It is also a good use of the limited space in the classroom because it leans on the back of Samantha's desk and only sticks out a little to fit the reservoir.
Strengths: This design is space efficient and won't take up a lot of floor space because it would be backed up on Samantha's desk for support. The zig-zag tubing of PVC pipes allows for water to flow freely down to the reservoir, giving the user a low maintenance product. Since this design will be the height of the table, it gives the students easy access to water the plants or monitor the water level in the reservoir.
Weaknesses: This system is at a level where it can be kicked or tripped over when passing by. It could also be hard to move if something needs to be fixed because of how close it is to the ground. Even though the zig-zag design helps the water flow freely, it could cause an uneven distribution of water problem when watering the plants. The first and last plant would probably receive the most water.

Light Source Hydroponics System

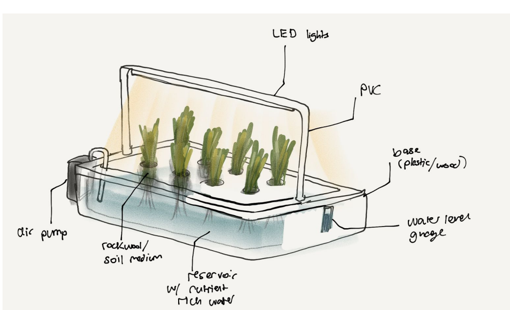


Figure 14: Light Source Hydroponics System

Tagline: A compact hydroponics system that has its own built-in light fixture and can be placed in tight spaces within the classroom.
Core need: Samantha's classroom poses space constraints. This design is compact and fits on the counter next to the sink without obstructing the view. The built in light source helps to ensure that the plants with grow properly and evenly with low maintenance.
Strengths: This design has its own light source which

ensures that all of the plants will receive light more directly. Since this design is intended to be relatively compact, it would be possible to make multiple; this way groups students could have ownership over a few of the plants and be responsible for looking after them.
Weaknesses: With the built-in light source and air pump, the price of this design could potentially be higher than the others.

Aquaponics System

Tagline: An interactive and educational aquaponics system that utilizes fish as a nutrient source to nurture the garden on top.

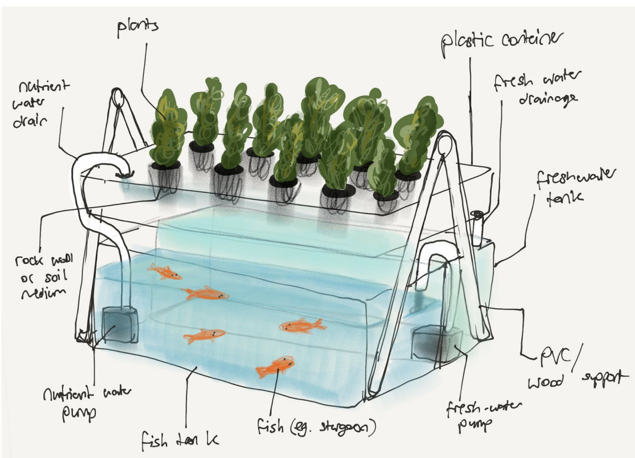


Figure 15: Aquaponics System

Core need: Samantha wants to create an educational and engaging project for her students. She also believes that the classroom and school needs a lot more green spaces in order to benefit the student's education and wellbeing. This system creates an interactive and educational experience for the student while at the same time producing greenery for the classroom.
Strengths: This design provides a more interactive and educational experience compared to the other designs. This system does not need added fertilizers to grow the plants as it uses the wastes that fishes excrete as nutrients. It uses PVC pipes to support a mini garden in the top and has a pump within the aquarium to circulate water into the garden. Adding fish into the system will make the children a lot more engaged in this project, thus making the whole project and experience a lot more interactive.
Weaknesses: An aquaponics system will require a lot more materials compared to a regular hydroponics system, thus the cost of construction is a bit more. Although it is a lot more effective and efficient compared to the other designs, it is a lot harder to maintain. To prevent the water from smelling and stagnating, you will need to take out and replace the water inside the system at least once every two weeks. It's also a bit heavier because it utilizes a lot of water inside the aquarium.

Associated Educational Curricula
The associated educational curricula to support student learning of the design and engineering of hydroponics systems will be through the user manual we provide. The manual will teach the user what the different components of the hydroponics system does. It has instructions on how to build the system in case it needs to be recreated or if something needs to be fixed. This manual will also teach the user how to test the pH and keep the nutrient filled water at a good level. The manual is in the appendix for reference.

Research for the different techniques are referenced in the references section.

4. Concept Evaluation & Selection

Table 2: *Criteria for evaluation.*

Criterion	**Definition**	**Metric**
Usability	Can be maintained easily, students can easily reach it, simplicity of the system, easy to understand how it works, how easy it can be to take it apart and put back together, can easily be moved from location to location	Weight of the final product (lbs) Dimensions of concept - height, width, depth Number of different components
Sustainability	Components last a long time and does not degrade, system can be reused, plants can be easily switched around, uses small amount of energy and water resources	# of uses after each plant life cycle Amount of electricity and water use
Desirability	Very engaging to students and teacher, conveys educational lessons	# and quality of interactions (qualitative evaluation and observation)
Feasibility	How easily it can be constructed, how well it can fit into space of classroom, how maintenance schedule fits into user's schedule, use is intuitive to target user	Build time Availability of materials Path and time it takes user to understand concept Time required to maintain system
Durability	Materials/components hold together and withstand wear and tear, structural integrity is maintained	# of structural failures Visible deformities after use
Affordability	Cost of materials and assembly do not exceed budget	Combined initial cost of materials along with possible repair costs
Efficacy	How well plants grow, how much educational value the students derive from project	Plant size, colors, stage of growth (species specific) Student reviews and qualitative feedback

4.2 Evaluation

Introduction

Concept 1: Zig Zag Hydroponics System

The Zig Zag Hydroponics System is both usable and affordable. The structure would include PVC pipes, a reservoir, a pump, and plants, all of which can be bought at a local hardware store at a reasonable price. Maintenance would not be a huge hassle because of the simple components. The students can learn how the hydroponics system works overall by taking care of the plants and maintaining the system. Overall, this concept is easy to use, affordable, and educational. It could be placed on any flat surface, ground, or table and it would be easily accessible by the the students. This design would satisfy the efficacy criteria since each socket would be a slot to put a pot and every time a new group of students enter in the new school year, they would be able to choose something they want to grow, and place it in the slot. It is sustainable because a new structure doesn't have to be made every time new plants are needed to be put in. It will reduce mess because all plants would be in a pot, not directly inserted in the system.

However, this structure might not be very feasible. It would most likely be put on the ground in front of the teacher's desk, where the height of the system would be around 3 feet. Since this structure is on the floor, people could trip on it because it sticks out.

Concept 2: Aquaponics System

The Aquaponics system satisfies both the efficacy and desirability requirements. The use of fish in addition to the plants would bring an additional educational concepts that the students could learn. Samantha Lee agreed that having a class pet in addition to a hydroponics system would make the kids very engaged during their lessons. Additionally, this system would be sustainable as it would recycle water and use the fish as a natural source of nutrients for the plants, creating an ecosystem of sorts. The system is also durable and would be able to be reused as long as the tank itself remains intact and is placed in a safe location.

As a result to the added components, usability will be a bit harder due to the complexity of the system and it might not be as feasible compared to the other designs because it requires more maintenance and care. Affordability might be another concern because you will need to buy more materials to construct this system and the associated cost of the fish might raise the overall price of the system.

Concept 3: Light Sourced Hydroponics System

The Light Sourced Hydroponics System is compact and feasible. Out of the possible concepts, this concept is the easiest to construct and is the easiest to maneuver based on user needs. The user needs a structure that fits into the space constraints of the classroom. We have identified the countertop as the most probable location for a system. This concept will fit that space perfectly while still remaining accessible by students. Based on our research of similar systems, the construction and installation of this system is relatively easy. Parts and components can be easily secured and maintenance would be minimal. The LED light ensures that plants will receive evenly receive nutrients passively without the necessity of constant user maintenance.

This system is more expensive than others and provides less of an interactive and educational experience for the students. The cost of a suitable LED light would take up a large portion of the proposed budget and would have to be changed out manually if it were to fail in the future. One of the user's main needs was for a system that provided a educational component for the students. Although the students would be participating in the build and procurement of this system, other options provide a much deeper understanding of how a hydroponics system works and what engineering concepts lay underneath the product.

Concept 4: Hydroponics Tower System

The Hydroponics Tower System is durable and feasible. This concept is probably the most structurally sound; the sturdy base provides a foundation for the PVC pipes. It also is one of the more feasible with respect to the spatial constraints of the classroom. We are planning on looking for ways to use recycled material (e.g. netted produce bags used to hold plants) and the system itself will recycle used water which makes this a sustainable and affordable design. The clear base will make the roots of the plants visible. This, along with a manual and lesson plan could help teach students concepts relating to hydroponics which would make this concept desirable for Samantha and engaging for the students. The ability for students to learn more about constructing and maintaining this system also provides educational value which satisfies the efficacy criteria.

This system may be less usable than other concepts. This structure is more bulky and therefore difficult to move around compared to the Light Sourced Hydroponics System. The entire structure could potentially be very heavy, making it difficult for Samantha or the students to maintain the system or move it as needed. Additionally, the height of the tower can become a concern; if it becomes too tall, it will be difficult for students to reach the plants at the top.

Research Methodology

In creating these four concepts, we had to keep in mind the design criteria to ensure that our system answers our users needs. However, each concept has its own unique strengths and weaknesses and ultimately cannot answer every need without sacrificing another. The most important factors that we had to consider when discussing our concepts were cost, usability, sustainability, and durability. To evaluate cost, we had to consider what kind of materials we would use for each concept and try to minimize cost without sacrificing too much quality. We did this by visiting stores and sites that carried the materials necessary for our project and comparing prices in order to minimize our expenses.

To evaluate usability, desirability, and feasibility we interviewed Samantha for feedback on our solutions. In our interview, we asked questions about aspects of each design such as the relative ease of use, time needed to maintain each structure, and price in order to gauge how each design concept performed against each criteria.

Results

We chose a final solution based on Samantha's feedback. Below are feedback capture grids for each of the four concepts that we presented to Samantha:

Table 3.1: Concept 1 - Zig Zag Hydroponics System Feedback

What works: Likes the idea of each student having their own plant (responsibility factor)	**What can be improved:** Would have to constantly monitor student interaction with it since it's a mostly open system
Question: Would this create a tripping issue?	**Ideas:** Scale it down to smaller version to fit the counter

Table 3.2: Concept 2 - Aquaponics System Feedback

What works: Likes class pet idea. Riskiest but coolest option	**What can be improved:** Concern over maintenance. Less realistic because she knows she'll get busy and be lazy about maintaining it
Question: What happens when the fish dies?	**Ideas:** teach the students that it's a natural life cycle

Table 3.3: Concept 3 - Light Sourced Hydroponics System Feedback

What works: Safest option out of all the concepts	**What can be improved:** Find ways to make it more interactive/visual
Question : How will the price of the light affect the budget?	**Ideas:** research to find an affordable light that can do the same job as a pricier one

Table 3.4: Concept 4 - Hydroponics Tower System Feedback

What works: Likes idea of a clear base so students can see the roots/system in action	**What can be improved:** Concern over the height/size of the structure
Question : Would we be able to keep the entire height under 3ft? Is it possible for students to use tools to help during installation?	**Ideas:** Wants a manual with clear directions as to maintenance (when to change water, add nutrients, etc)

Discussion

In our evaluation of the initial concepts that we created, some concepts fit our evaluation criteria better than others. Overall, it seems that the best option for this project is either the Hydroponics Tower System or the Zig Zag Hydroponics System. The Zig Zag system is constructed entirely of low-cost PVC piping, with holes to be made in the piping to fit a plant for each student. By allowing each student to be responsible for their own plant, a sense of responsibility is given, improving the efficacy score of this system. In addition to this, the Zig Zag system also takes advantage of a water pump and gravity to cycle water throughout the system. This cycling of water ensures that nutrients are less likely to be wasted, giving this system a high score in the sustainability criterion. Similar to the Zig Zag system, the Hydroponic Tower system also takes advantage of recycled water to reduce waste. It is also desired for this system to use recycled materials in its construction, which gives it a high score in both the sustainability and affordability criteria. Furthermore, the Tower system is partially composed of transparent PVC that would allow the students using it to see the roots of the plants in the system. This provides for an additional education opportunity, improving the efficacy of this system. These two systems are both affordable and highly usable without sacrificing efficacy or sustainability.

4.3 Selection

Pugh Chart showing concept evaluation of all four generated concept designs, as well as two hybrid designs. The first is a tower design, Design 4, that utilizes the shell of Design 1, with the mechanism of an aeroponic mist system which employs a pump and sprinkler tubing to provide plant roots with hydration and maximum oxygenation. The second hybrid design, Design 5, is a deep water culture system that is designed to be placed near a windowsill in order to use as much natural light as possible. It will incorporate a similar body style as Design 2, but will not have a build in lighting feature and will use an air-pump and airstone for aeration and introducing dissolved oxygen into the water. It is also the most affordable design. Our full Pugh chart can be found in the Appendix (Table 4).

5. Design Draft

5.1 Overview

The hydroponics tower system introduces more greenery into Samantha Lee's classroom while still providing her students with an interactive and engaging project that aims to teach them about the concepts of hydroponics and sustainable farming techniques. The tower is at a height where students can still tend to the plants while still taking advantage of the available vertical space within the classroom. The clear base serves as the reservoir where students will be able to monitor important aspects of the hydroponics system such as the water pump, the water level, and pH levels of the solution.

Coupled with our lesson plan, this hydroponics tower system will serve as an hands-on, educational project for the students. They will not only learn about the parts that make up the system but also how these parts must work together in order to successfully produce thriving plants. In order to gain a better understanding of the hydroponics system, the students will assist in the final steps of constructing the system. Within the structure of the classroom, students will be responsible for tending to the plants and making sure that the hydroponics system is continuing to work properly.

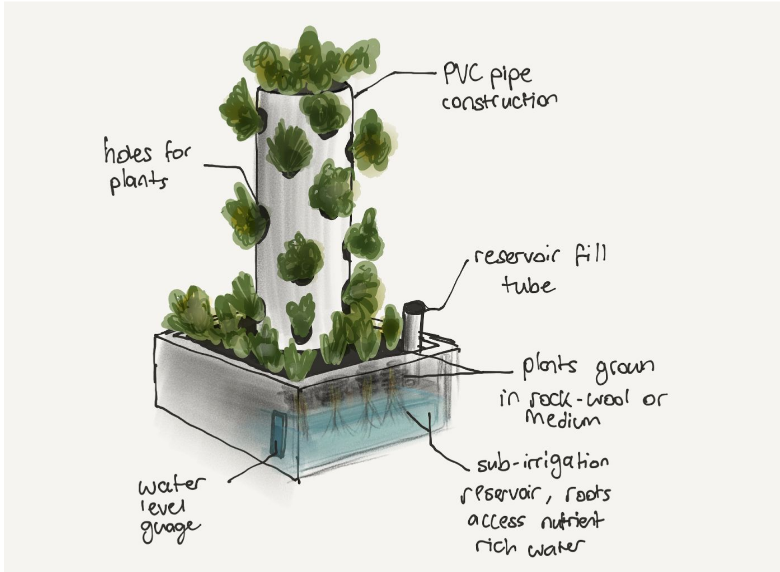


Figure 15: Sketch of Hydroponics Tower System.

5.2 Detailed Design & Implementation

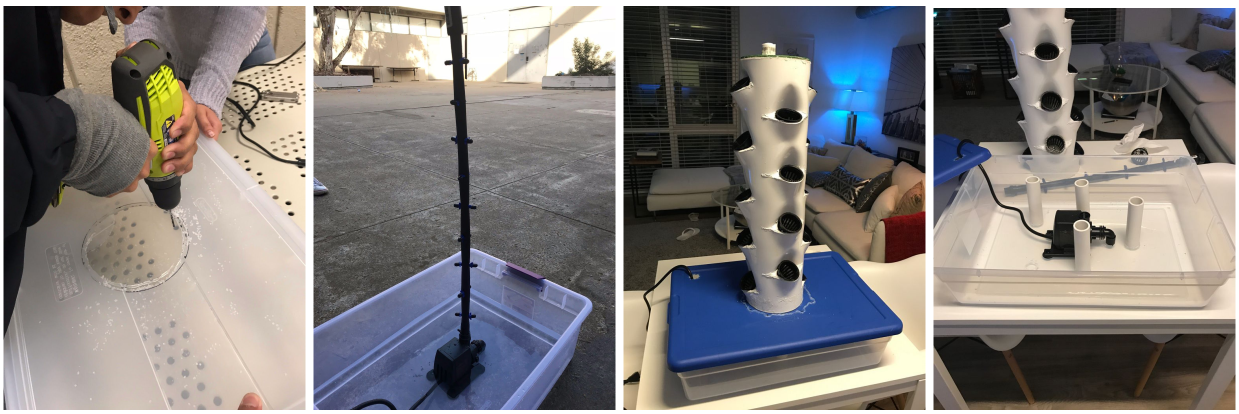
As seen in the figure above, the Hydroponics Tower system is comprised of the following parts: a PVC pipe (2 feet tall and 6 inches in diameter), smaller PVC pipes to hold the base, a container that holds the tower and water, a pump, sprinkler heads, pots that will hold the plants, rockwool for the plant medium, and of course an array of plants. As for the tools needed to help build the system, you'll need: a heat gun, a saw, a thick wooden dowel, a Dremel or drill, and a towel. A comprehensive list of all the materials used and their cost can be found in the Appendix (Table 5.1 and Table 5.2).

Figures 16-20: Plant Holder Set Up.

Steps 1-6 Plant Holder Set Up:

1. The first thing to do is to make small 5 inch incisions into the 2 ft PVC pipe on two sides using the saw. (20 mins) View detailed diagram in appendix.
2. Create the same small 5 inch incisions on the two other sides except this time you are only making two incisions. (20 mins)

3. Apply heat gun on top and below the incisions. You must apply heat for about one to two minutes in order to make the PVC malleable
4. Once the PVC is malleable use the wooden dowel to create two inch holes that will hoist the mini plant pots. Insert wooden dowel into the incision and push down on the dowel with enough leverage to create an indent inwards and outwards.
5. Once the dowel is inserted, cool down the PVC pipe using a wet towel so that the PVC can harden once again.
6. Once the PVC is cooled, ensure the hole is of the right size by inserting the 2 inch plant pot. The plant pot should fit snugly inside the hole. (2 hours for steps 3-6)



Figures 21-24: Water Pipe installation.

Water Pipe installation

1. Similar to the PVC tube incisions, make a mark 2 inches into the sprinkler tube.
2. Continue making marks every 5 inches from the initial mark.
3. Flip tube 180 degrees and repeat
4. Turn tube 90 degrees and make an incision 4.5 inches into the tube
5. Continue making marks every 5 inches from the initial mark
6. Flip tube 90 degrees and repeat
7. Using the hole puncher, make holes by pressing the tool into each mark made on the tube
8. Press the sprinkler heads into each hole, and attach the compression cap on the top.
9. Attach the tower on top of the cover and sprinkler system and you're done!
10. Cut and attach pillars onto the lid and the base as show in in the appendix diagram(60 minutes for steps 1-10)A Detailed diagram in appendix.

The hydroponics tower system will be situated on the countertop in Samantha's classroom. Rather than conducting the entire build on site, components of the system will be prefabricated by the team. The parts will then be installed and assembled on-site, presenting the students with an educational opportunity to understand the science behind the project while also allowing the team to present the solution in a timely manner. Prefabrication of the parts also allows for greater accuracy and gives the team a chance to test the system prior to installation. On-installation should not take more than 20 minutes. The remaining time in the classroom will be devoted towards the educational component of the solution.

5.3 Assessment

Our solution matches up with the user's needs. Samantha wanted a way to educate her students about green space by having an interactive system for them learn from. She is hoping that the hydroponics system will get her students interested in growing plants and caring more about the environment. The hydroponics system gives the students a fun way to grow plants and learn about how the system works. It has a unique structure that could capture their attention. Young kids are always interested in learning how "cool" things work, so we can see them being engaged in helping grow plants and maintaining the system. Naturally, if you are interested in something, you would take the time out to learn about it and find out more information about it. We are hoping this will happen for the third graders. The hydroponics system we are building is simple enough to recreate. We are planning to make a lesson plan to educate the students and we will include an instructions manual to let them know how to maintain the system and how we built it. This way, the students or Samantha would be able to reproduce it if they would like. However, it does require tools that thirds should not get their hands on. Some parts of the system would have to be built by an adult. When they use the hydroponics system we build for them, they can see what they like and dislike about it. They can then give us feedback and we can create a new and improved design for them if they would like. Educating the students about creating a greener and more eco friendly environment at an early point in their lives can help ingrain in their minds that this is something that will help make the world a better place to live in. They will be growing up with the mindset that they need to be eco friendly, which tackles the problem from the start and therefore will be conscious about the environment. The new generation will be educated and hopefully little by little, they will make a difference in the future with what they learn about the importance of green space.

We may be able to assess the effectiveness of our solution by maintaining a line of communication with the primary stakeholder, Samantha Lee. Our team would check in regularly with Samantha, and ask her questions about the state of the project's solution. Such questions would include inquiries into the physical state of the project as well as the amount of engagement the project is having with the students. Information about student engagement would help our team gauge the amount of educational impact that our project has had on the students at UDA. Positive or negative feedback with regards to these aspects of this project will give us information on the project's overall effectiveness and social impact.

Our primary stakeholder, Samantha Lee, defined the problem that we are solving, which is to create an educational green space for third grade students at the Urban Discovery Academy. Our team developed an educational hydroponics system as a solution to this problem statement. Those who directly benefit from our solution are Samantha Lee and her third grade students at UDA. If our solution is effective in addressing the problem, future students as well as the school board of UDA may benefit as well. In a similar way, Samantha Lee is also burdened by our solution as she becomes responsible for maintaining the system. If our solution is shown to be ineffective in its implementation, the students at UDA may be burdened by its lack of success as well. The students would be burdened if our system does not provide an effective educational green space as its ineffectiveness would serve as a distraction from their normal coursework. Our solution encourages the consumption of a small amount of resources for the sake of the education of Samantha Lee's third grade students. The system requires a small amount of dirt as well as a constantly flowing supply of nutrients, water, and power, which results in a small amount of continuous resource consumption. The impact of this consumption is ultimately not very high, as it was designed to be low-impact and relatively sustainable. Using a water recycling system in our solution also mitigated the ecological degradation that could be caused by our solution.

The short-term and long-term ecological and economical impacts of our solution will also be assessed by communicating with Samantha. Feedback on the amount of resources used by our solution will give us information about our project's ecological and economical effectiveness. For example, the system may not be effective from an ecological standpoint if Samantha notices that the project requires a disproportionate amount of dirt or nutrients to grow the plants in the system. Similarly, the system may be shown to be economically ineffective if it becomes financially infeasible for Samantha to continue using the system. Positive or negative feedback with regards to these aspects of the project will give us an idea of our solution's overall ecological and economic impact.

We have attempted to think up all possible problems our solution may create in the classroom setting. We believe of these possible problems the most glaring one would be the problem of children's attention shifting away from the teacher's lessons and to the solution. One rubric we have used to measure the success of our project is the student's interest and engagement with the solution. The unforeseen defect of this rubric is that the students may become too interested and too engaged, taking away from their elementary school education.

Another possible problem our solution may cause deals with the structural stability of our system. Since our system utilizes a two-foot tower attached to a one-foot tall container on top of the sink counter in the classroom, this might create a falling hazard for the students. There are times when students become a bit too playful with something they're really interested in. If they somehow pull the system with enough force, it might fall on top of them, causing physical injuries and trouble for us and Samantha Lee. Will the opportunity for an educational experience be worth the risk of possible physical injuries to the students?

Lastly, we thought that it might cause additional stress for Samantha to maintain the system. Although we designed our project to be fairly simple and automated, Samantha would still need to make sure that all parts are working correctly and the plants are growing at an acceptable rate. If a certain part happens to stop functioning, then it will be up to Samantha to either buy a replacement part or stop using the system.

6. Conclusions & Recommendations

The main goal for the Hydroponix team was to create an interactive and immersive experience for a third-grade classroom in downtown San Diego. Our design solution will enhance the greenery and oxygen for the third-grade classroom in Downtown San Diego while also teaching the students about engineering and design principles. We reached our design solution by following the Human-Centered Design Process: Empathize, Define, Input & Feedback, Ideate, Input & Feedback, Prototype, Input & Feedback, and Test. Through stakeholder analysis the group found our main stakeholders to be Samantha Lee (Third grade teacher of the classroom), the students of the class, professor Brandon Reynante from UCSD Global Ties, the parents of the third graders, Urban Discovery Academy Board of Trustees, other teachers from UDA, and UCSD. The group planned to research the fundamental needs of the stakeholders by interviewing Samantha Lee, her students, and their parents. The group also conducted online research to find more background information on UDA as well as existing solutions that pertain to the scope of our project. After research and team collaboration, the Hydroponix team found the problem statement: Samantha Lee and her students need a low-maintenance, affordable and interactive educational experience relating to plant sciences, that complements their curricular science education, and modifies their sterile urban classroom into a greener space. UDA was found to be a free-public charter school with grades K-8th grade that focuses on creating an interactive learning experience for their students which integrates real-world applications in concepts like science, engineering, and business. Although the initial concepts for the school are progressive and interactive, the location that the school is in, downtown SD, does not provide a conducive environment for learning and does not provide a sense of nature or greenery. The needs and insights that the group gained from their research included: a need for an educational supplement in the creation of a green spaces that ties into the current topics being taught by Samantha Lee, an interactive science experience that teaches more sustainable farming methods, a need for affordability, and finally a need for an aesthetically appropriate design solution. Through the course of the quarter our team was able to find an appropriate hydroponics system that would fit within the constraints of the classroom. The final design solution that we chose was a type of aeroponics system, a subsection of hydroponics, that the group was able to design based on the concepts that the group generated from finding out about the analogous design solutions that already existed.

In the future the Hydroponix's hopes are that the school possibly adopts a type of hydroponic system throughout the other classrooms as well. The group designed their solution to be affordable, interactive, and easy to rebuild so that other designs of the project can be adopted if the school decides to. Another hope that the team has for the future is for the idea of sustainable farming practices to be adopted by the students as they grow older and for them to influence future generations to come.

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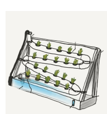
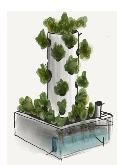
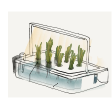
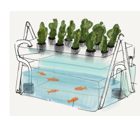
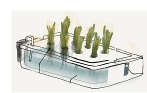
Appendix

Table 4: *Pugh chart*

Description		Zig-Zag/ Ebb & Flow	Tower Design, Sub-Irrigation	Light sourced aquacul-ture	Aquaponic Model with fish	Tower Design, Aeroponic Mist	Aerated Deep water Culture
Diagram							
Criteria	**Weight**	**Datum**	**Design 1**	**Design 2**	**Design 3**	**Design 4 (Hybrid)**	**Design 5 (Hybrid)**
Usability	3	0	-	+	0	+	+
Sustainability	1	0	--	+	++	0	0
Desirability	1	0	0	0	+	++	0
Feasibility	2	0	++	0	-	+	++
Durability	2	0	++	++	+	+	++

Affordability	3	0	+	---	-	+	++
Efficacy	3	0	-	+	+	+	0
+		0	8	11	8	15	17
0		15	1	3	3	1	2
-		0	8	9	5	0	0
Net Score		**0**	**0**	**2**	**3**	**15**	**17**

Table 5.1: *List of materials required.*

Materials Required	Cost ($)	Materials Required	Cost ($)
6”x 2’ Long PVC Pipe Vendor Link	8.97	210 GPH Submersible Pump Vendor Link	19.96
1” PVC Pipe (bulk) Vendor Link	3.91	Spray Paint Vendor Link	3.67
PVC Drain Cap Vendor Link	4.89	18 2” Net Pots Vendor Link	4.40
1/2 “ vinyl tubing Vendor Link	12.98	Rockwool Grow Cubes Vendor Link	9.49
Sprinkler heads x3 Vendor Link	9.54	Liquid Plant Nutrient Solution Vendor Link	9.98
28 qt Plastic container with lid Vendor Link	8	Epoxy Putty x2 Vendor Link	11.94
Hot Glue Sticks Vendor Link	8.92	Plug Timer Vendor Link	12.98
½ Inch Compression End Cap Vendor Link	1.55	pH Test Strips Vendor Link	5.50
		Total including Tax (12.64)	**149.32**

Table 5.2: *List of tools required.*

Tools Required	PVC Cutter (minimum 1”)
Power Drill with 1/4” and 2” drill bits	Saw (Electric or Manual)

Protective gear: Respirator, Goggles, Gloves	Protective gear: Respirator, Goggles, Gloves
2” Wooden Dowel with 45 degree cut on end	Hot Glue Gun
Heat Gun	2” Wooden Dowel with 45 degree cut on end
Vinyl ¼” Tube hole punch	Permanent Marker (Sharpie)

Meeting 1
Date: October 13, 2017
Duration: 3pm - 4pm

Attendance List:
1. Victoria Tam
2. Lauren Gong
3. Rasheed Al Kotob
4. Jan De Castro
5. Jeremy Borja
6. Edward Lin
7. Francisco
8. Owen
9. Daniel Vazquez

Summary: This first meeting was meant to be a social. We meet up at Shogun’s play area to play games and chat in order to get to know each other better as a team. We switched off playing ping pong and billiards. This process took about 40 minutes before doing a formal meeting. In our meeting, we talked about our stakeholders, got into contact with her, and wrote some interview questions that might be important when we meet up.

View photos here

Meeting 2
Date: October 21st, 2017
Time Duration: 11:00 am - 1:30 pm

Attendance List:
1. Rasheed Al Kotob
2. Owen Chen

3. Victoria Tam
4. Francisco Ochoa
5. Jan Eric De Castro
6. Edward Lin
7. Lauren Gong
8. Daniel Vazquez
9. **Not present:** Jeremy Borja

Summary: Before meeting with Samantha Lee, a major stakeholder in this project, our group had a 2 hour meeting. During this time, we completed most of the first design report and discussed possible questions that we can ask Samantha. We also talked about splitting into different subgroups that will tackle different tasks and also go to UDA at certain times during the quarter to interact with the class.

Interview Notes:
Start Time: 12:55 pm
End Time: 1:30 pm

Information About Samantha

Samantha is a 3rd grade teacher at UDA who graduated from UCSD as an undergraduate majoring in Urban Studies. It is currently her 2nd year teaching at UDA. She really cares about her students and likes making experiences for her students to remember. She doesn't know much about hydroponics or botany, so she she's giving the team the freedom to choose the direction to go with the project. She believes that the connection with UCSD Global TIES and the program is amazing and should be maintained.

View entire interview notes here

Meeting 3
Date: October 28th, 2017
Time Duration: 11:00 am - 1:30 pm

Attendance List:
1. Victoria Tam
2. Lauren Gong
3. Rasheed Al Kotob
4. Daniel Vazquez
5. Jan De Castro
6. Jeremy Borja

7. Edward Lin
8. **Not Present**: Francisco and Owen

Summary of Meeting

Discussed and assign parts for the Problem Statement report. Since we weren't able to interview the UDA students directly, we interviewed and observed 3rd grade students during community activities. We also ideated on some possible concepts we can use when building the hydroponics system. We just searched through google of different hydroponics systems that might be easy enough to be built. We also searched through aquaponics and aeroponics system.

Wednesday: Should do sketches during work time Wednesday. ***By Saturday, should propose two final design decisions to Samantha.***

Budget?

- $150 or below

View the whole ideation list here

Meeting 4
Date: November 3, 2017
Duration: 12:30 - 2pm

1. Victoria Tam
2. Lauren Gong
3. Rasheed Al Kotob
4. Jan De Castro
5. Jeremy Borja
6. Edward Lin
7. Francisco Ochoa
8. Owen Chen
9. Daniel Vazquez

Summary: We went as a group to visit UDA in order to observe and interview the students in the classroom. During this visit we got a better idea of the space constraints within the classroom and talked to Samantha about various questions that we had regarding the logistics of any potential solutions that we would propose.We were able to ask the students about what they like about school, what was their favorite thing that they learned (and why), and what they know about growing plants.

Meeting 5
Date: November 4, 2017

Duration: 11am - 2pm

1. Victoria Tam
2. Lauren Gong
3. Rasheed Al Kotob
4. Jan De Castro
5. Jeremy Borja
6. Edward Lin
7. Francisco Ochoa
8. Owen Chen
9. **Not here**: Daniel Vazquez

Summary: This meeting was held on the day after our visit to the Urban Discovery Academy. We compiled all the information we got and observed from that visit and came up with additions to the ideas we had in mind. We received input from the class to see if they were interested in growing plants, so we could create a more interactive system that gears toward their needs and wants. From the visit to the UDA, we had a better idea of what kind of system was suitable for the classroom, so we created more designs based on the information we observed and the constraints given by Samantha. We also talked about the idea of using a rock wool garden for our hydroponics system, which was actually implemented in our final design.

View real-time meeting notes here: Meeting #5 Minutes

Meeting 6
Date: November 11, 2017
Duration: 11am - 2pm

1. Victoria Tam
2. Lauren Gong
3. Jan De Castro
4. Jeremy Borja (google hangout)
5. Edward Lin
6. Daniel Vazquez
7. Rasheed Al Kotob (google hangout)
8. **Not here**: Francisco Ochoa, Owen Chen

Summary: We had two meetings this week in order to work on the project. The first was Saturday at 11am to work on the team evaluation form. Since it was a three-day weekend, half of my group was gone because they went home. Thus, it was a little difficult completing the first evaluation form without our missing group members' inputs. But overall, it went pretty smoothly because there has been no conflict when it comes down to contribution and professionalism.

Meeting 7 (through google hangouts)
Date: November 12, 2017
Duration: 11am - 2pm, 5pm-8pm(shopping trip)

1. Victoria Tam
2. Lauren Gong
3. Jan De Castro
4. Rasheed Al Kotob
5. **Not here**: Francisco Ochoa, Jeremy Borja, Edward Lin, Daniel Vazquez, Owen Chen

Summary: We met over google hangouts to finalize the slides for our WIPP presentation. We took images from our previous drafts and included information about our progress on the project thus far. In the afternoon, we had a little shopping trip to grab some materials to start construction. Sadly, Home Depot and Target didn't have all the materials we needed so we had to order some of the parts online.

Meeting 8
Date: November 18, 2017
Duration: 6pm - 8pm

1. Lauren Gong
2. Jan De Castro
3. Jeremy Borja
4. Edward Lin
5. Daniel Vazquez
6. Rasheed Al Kotob
7. **Not here**: Owen Chen, Victoria Tam, Francisco Ochoa

Summary: We had a small meeting in regard to finishing the Concept Evaluation report and planning our trip to buy materials for our prototype. We didn't have the chance to do user testing because we lacked feedback from Samantha Lee but we did have a research plan ready. Thankfully, Samantha was able to contact us directly after the meeting to critique each of our concepts and pick the most viable Hydroponics system to put in her classroom. In the end, she really liked the tower hydroponics system.

Meeting 9 (First Building Meeting)

Date: November 30, 2017
Duration: 6pm - 8pm

1. Victoria Tam
2. Lauren Gong
3. Jan De Castro
4. Jeremy Borja
5. Edward Lin
6. Daniel Vazquez
7. Rasheed Al Kotob
8. Francisco Ochoa
9. **Not here**: Owen Chen

Summary: During this meeting, we began the process of building the hydroponics system. We began cutting and shaping the holes in the PVC pipe that would hold the plants. We also worked on creating the sprinkler system that would water the plants and cutting a hole into the top of the container that would be used for the base of the system.

Meeting 10 (Second Building Meeting)
Date: December 2, 2017
Duration: 11am - 3pm

1. Victoria Tam
2. Lauren Gong
3. Jan De Castro
4. Rasheed Al Kotob
5. **Not here**: Owen Chen, Jeremy Borja, Edward Lin, Daniel Vazquez, Francisco Ochoa

Summary: We continued the work that we started on during the previous meeting. We finished implementing the sprinkler system and making adjustments to the PVC tower. Rasheed also added a support system to keep the tower up. We made finishing touches such as spray painting the PVC tower and filling in the gaps of the holes we made with putty in order to prevent water from escaping.

Meeting 11
Date: December 9, 2017
Duration: 10am - 3pm

Attendance List:

1. Victoria Tam
2. Lauren Gong

3. Rasheed Al Kotob
4. Jan De Castro
5. Jeremy Borja
6. Edward Lin
7. Francisco
8. Owen
9. Daniel Vazquez

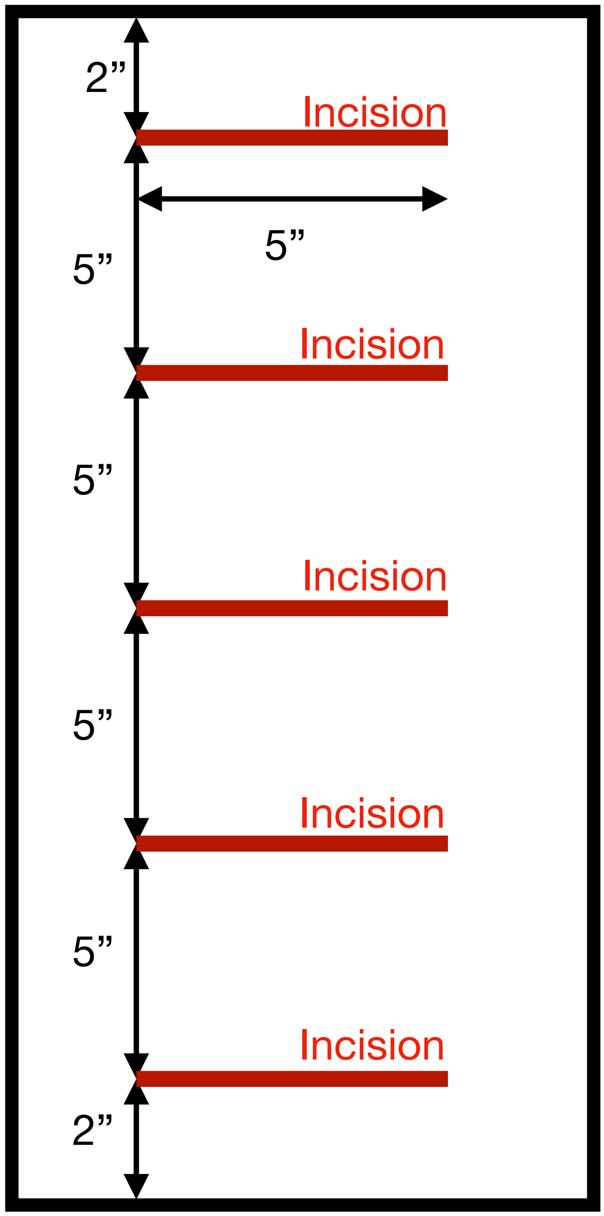
Summary: We worked on the second team evaluation and began working on making edits to our final report. During this meeting we split up the parts of the report that we got comments on throughout the quarter and tried to fix the information to adequately address them. Rasheed also worked on finishing the manual that we will hand off to Samantha along with the actual aeroponics system.

Meeting 12
Date: December 10, 2017
Duration: 10am - 4pm

Attendance List:
1. Victoria Tam
2. Lauren Gong
3. Rasheed Al Kotob
4. Jan De Castro
5. Jeremy Borja
6. Edward Lin
7. Francisco Ochoa
8. Owen Chen
9. Daniel Vazquez

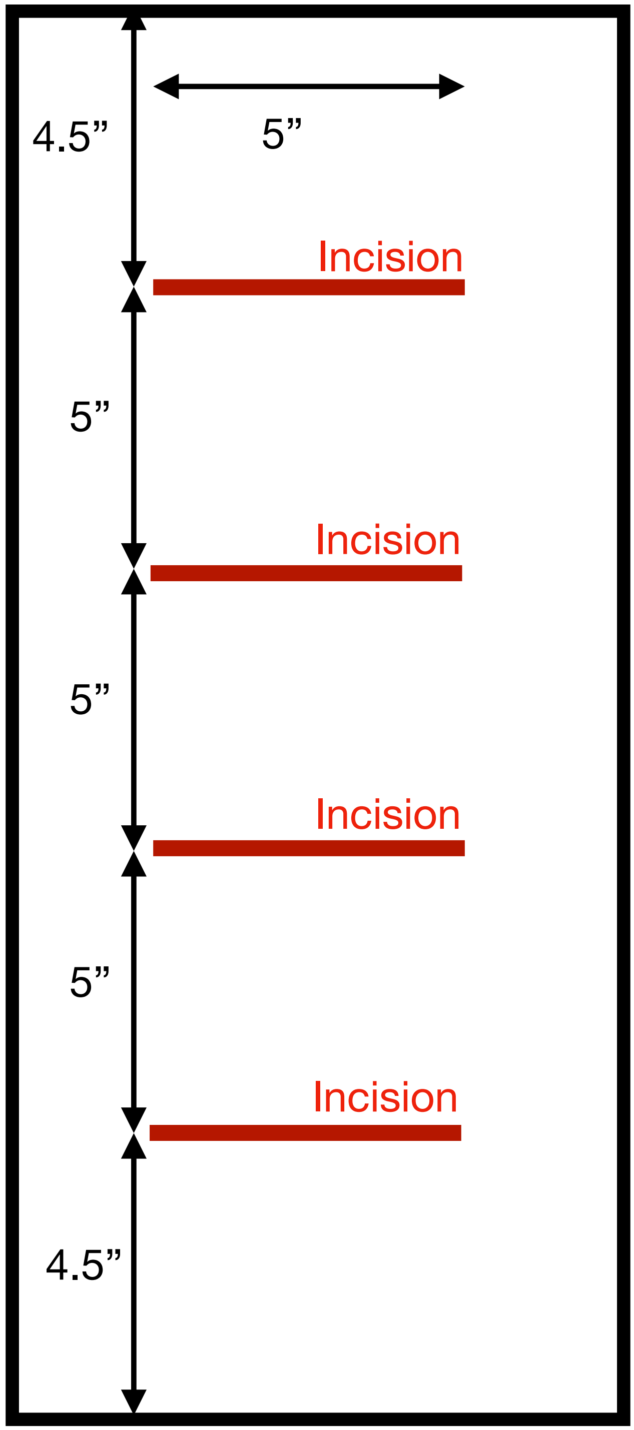
Summary: During this meeting, we submitted our team evaluations and finished up working on the final report and slides for the presentation. The majority of the time was spent changing the report based on the feedback professor gave us. Parts were split up for the presentation and we reviewed the report before submission. We also completed the presentation for the third graders. We had more team bonding for our last meeting, sang Christmas songs together, danced, and ate bagels.

Technical Build Schematics



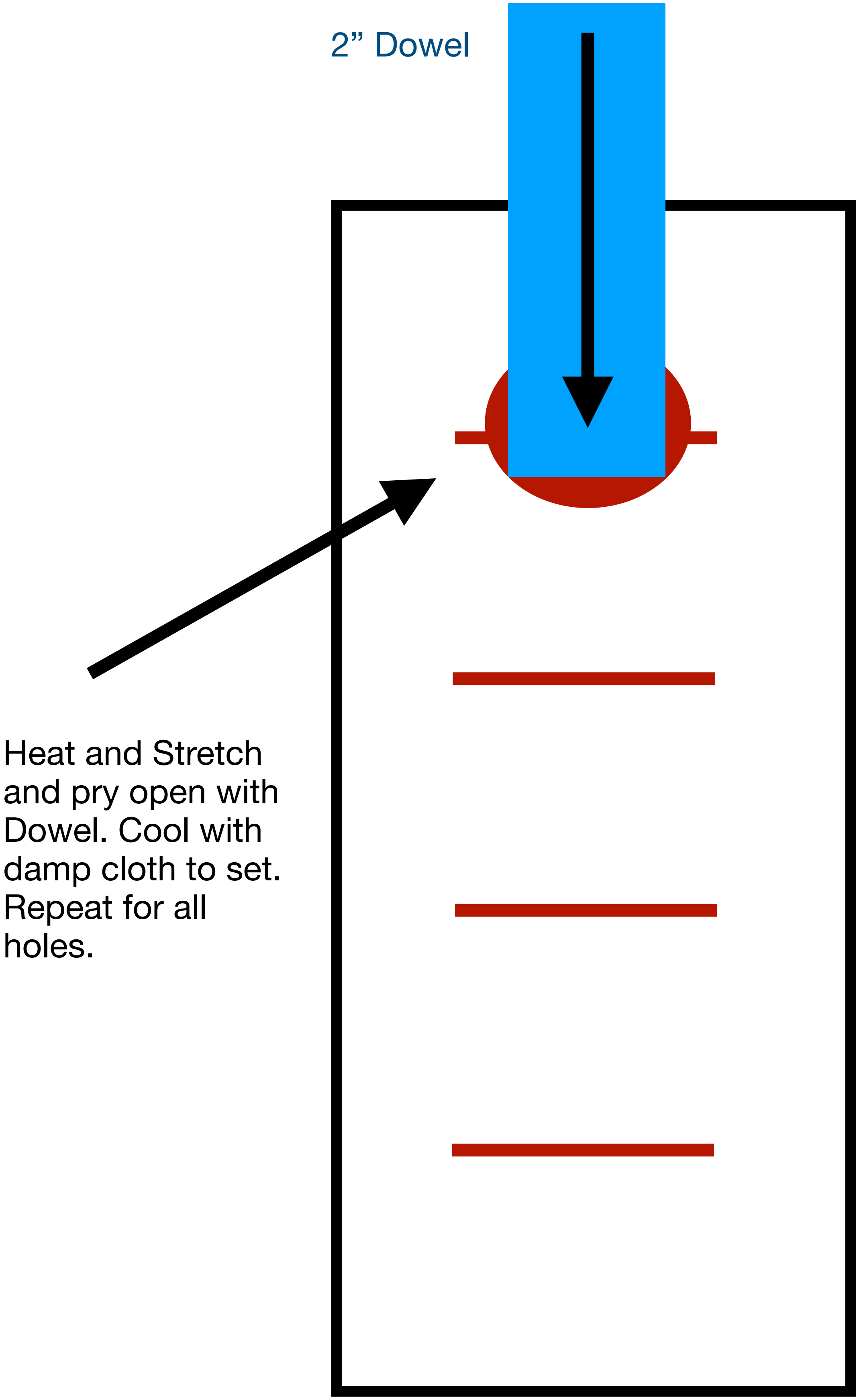
6” x 2 ft PVC Pipe

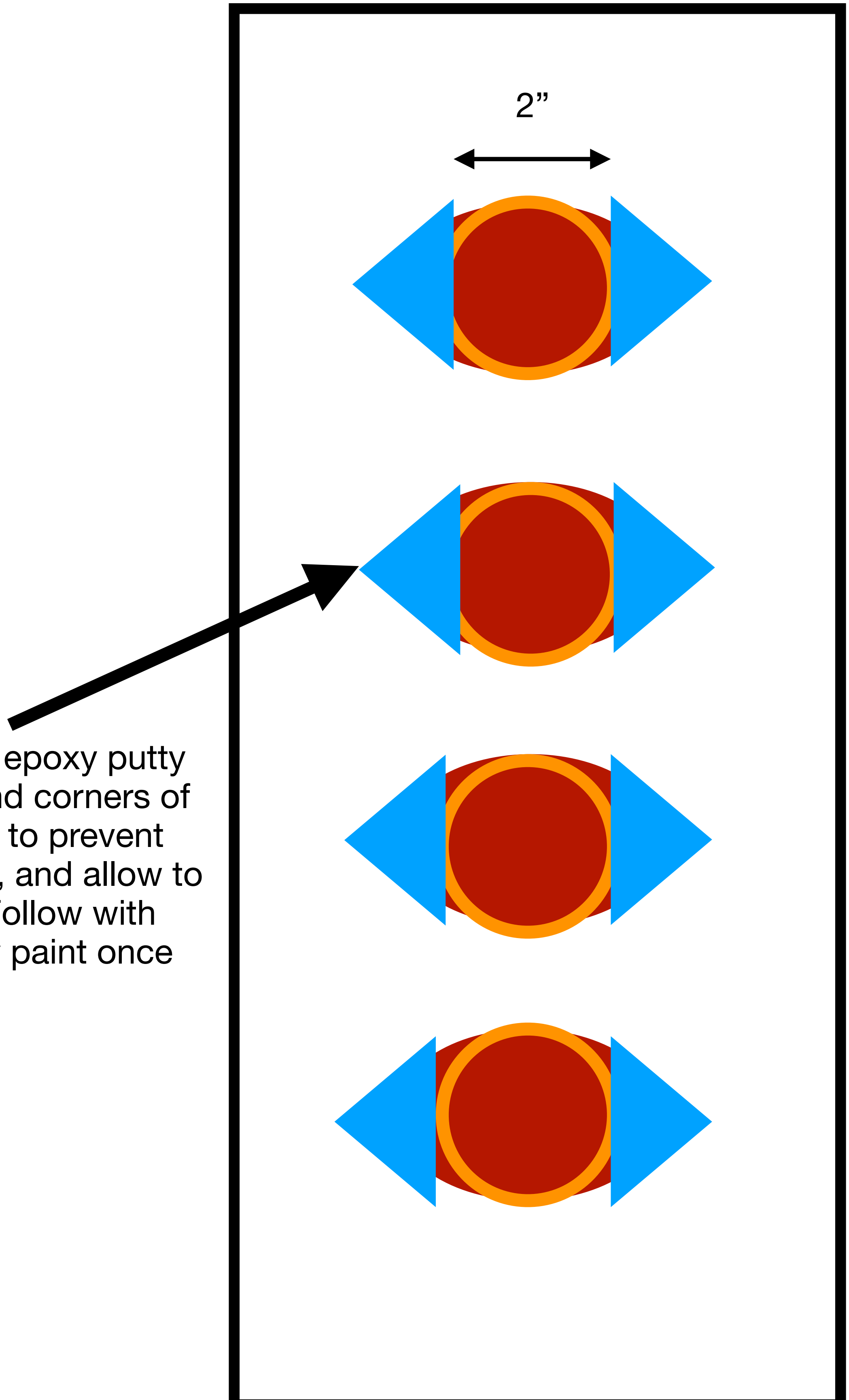
A - Sides (Opposite)



6” x 2 ft PVC Pipe

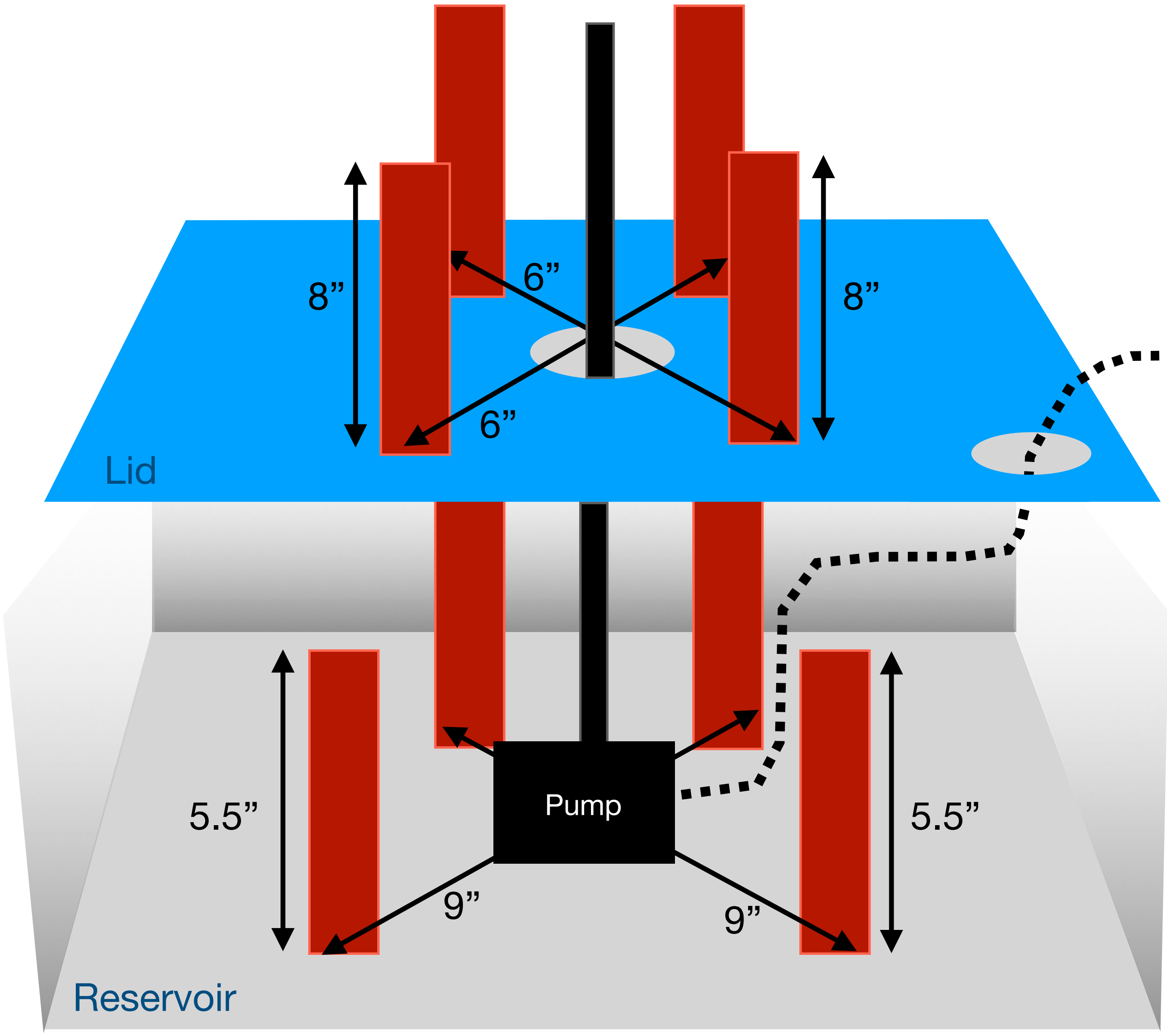
B - Sides (Opposite)


2” Dowel
Heat and Stretch and pry open with Dowel. Cool with damp cloth to set. Repeat for all holes.

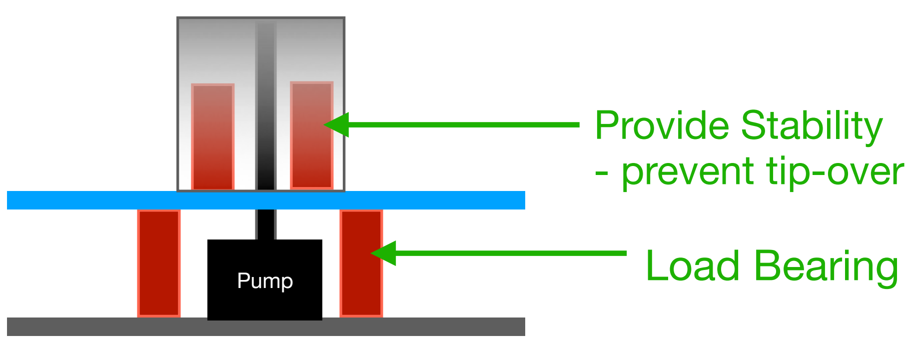


Mold epoxy putty around corners of holes to prevent leaks, and allow to set. Follow with spray paint once dry.

Place the 1” PVC support pillars on the lid and base using hot glue. Center them around the center of the unit, so that they provide support for the tower. This process requires empirical testing and finding what the ideal balance is in order to ensure that your system is structurally sound.



Cross
Sectional View:



Appendix 4: User Manual

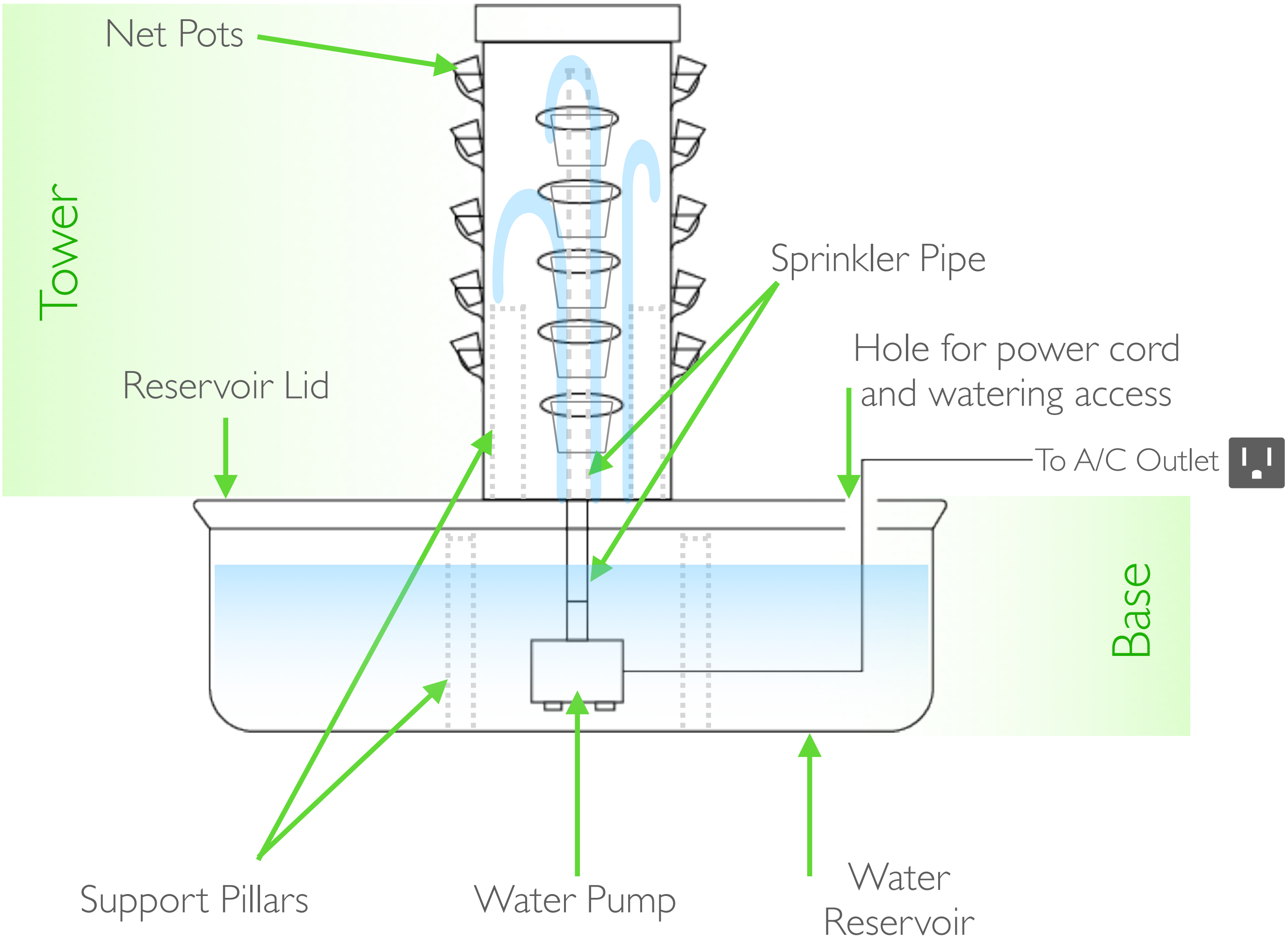
Aeroponix Tower System

by Hydroponix

A Simple User Guide

Contents

Unit Components

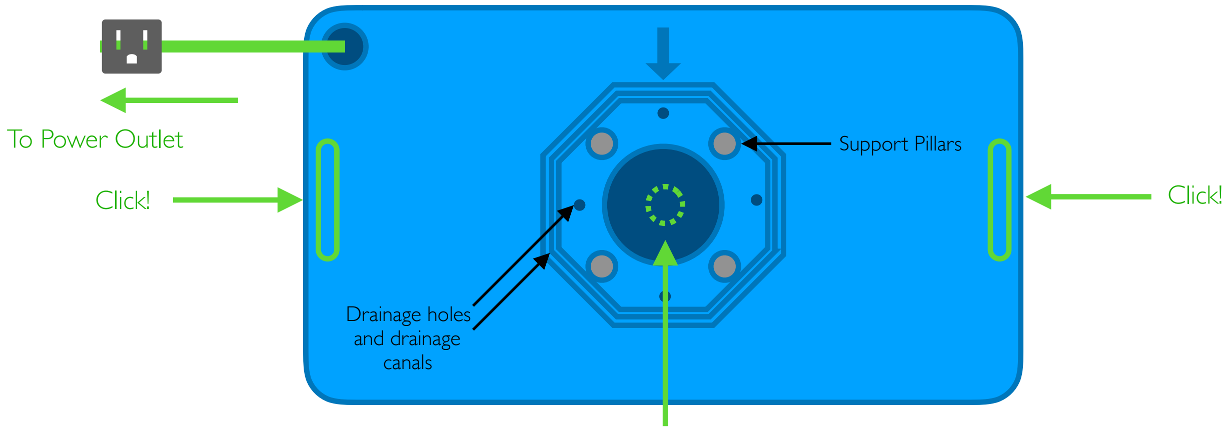


Other Important Components

Nutrient Solution	Rock wool	pH Test Strips	Timer Plug	Seeds
Will be diluted with water in the reservoir and will give the plants the nourishment they need to grow healthy and strong	This absorbed medium be used as "soil" for the seeds and goes inside the net pots along the tower wall	These are used to test the acidity/alkalinity of the water, to make sure the plants have the perfect water to grow	This allows you to set a schedule for when you would like the irrigation system to run and when to keep it off	These will grow to become beautiful lush plants in your Aeroponix Tower system

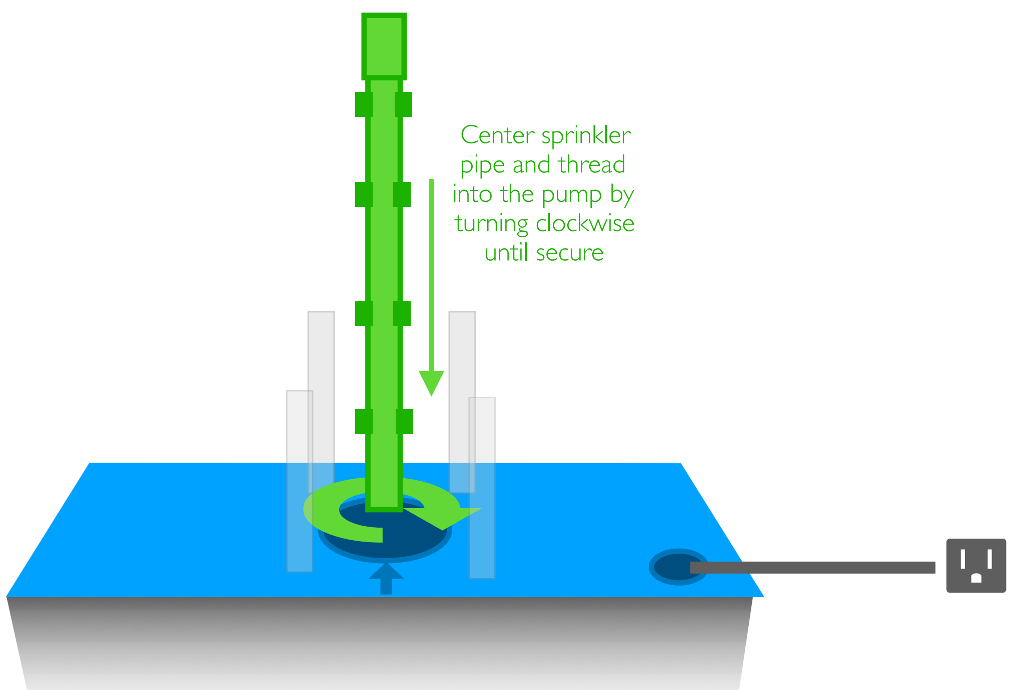
Quick Start Guide

1. Place the base on a stable surface, with close proximity to a power outlet.
2. Secure the lid onto the base, ensuring that the **pump** is centered below, the **power cord** is fed through the corner hole, and that that the lid is **clicked** firmly onto the edges of the container.

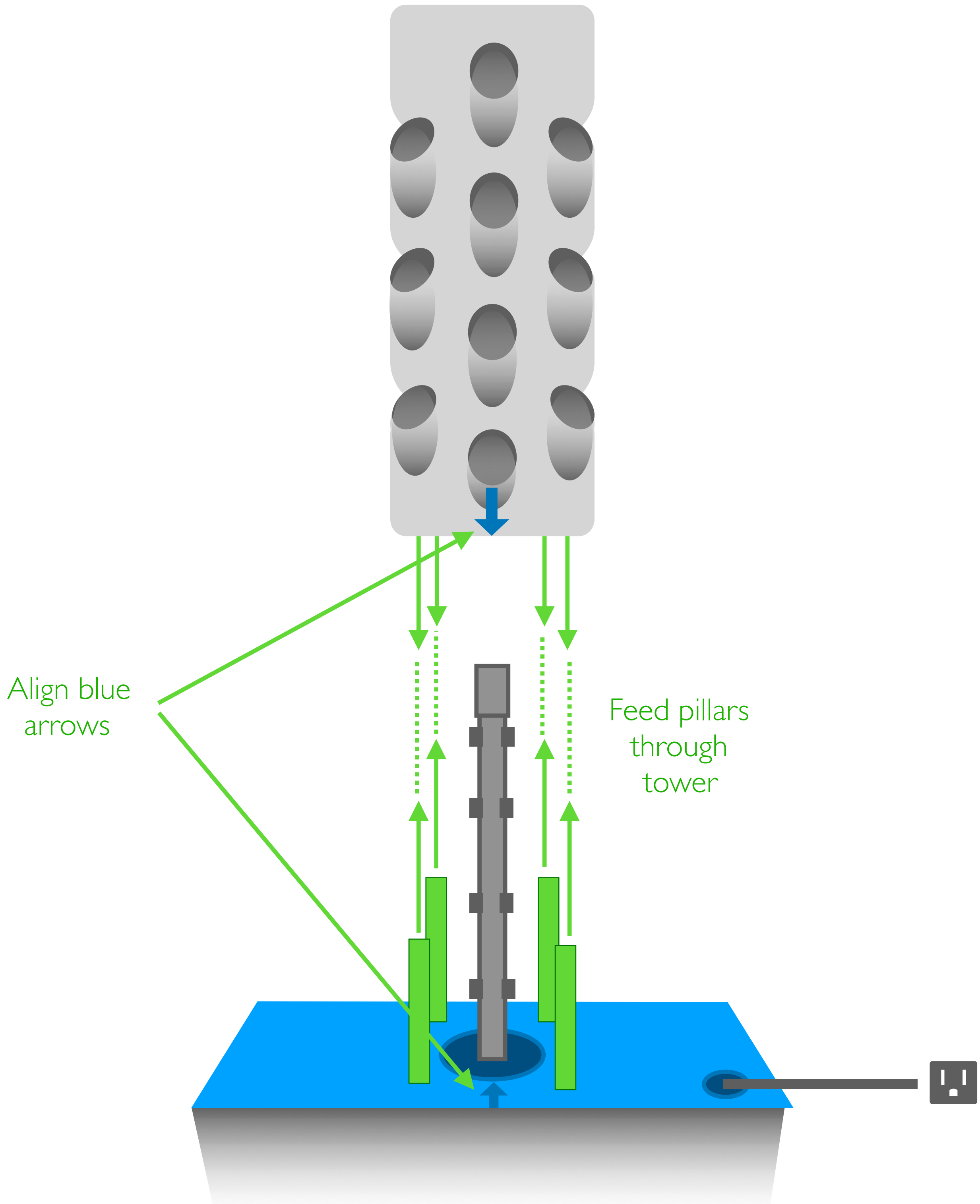


Center pump below hole in holder

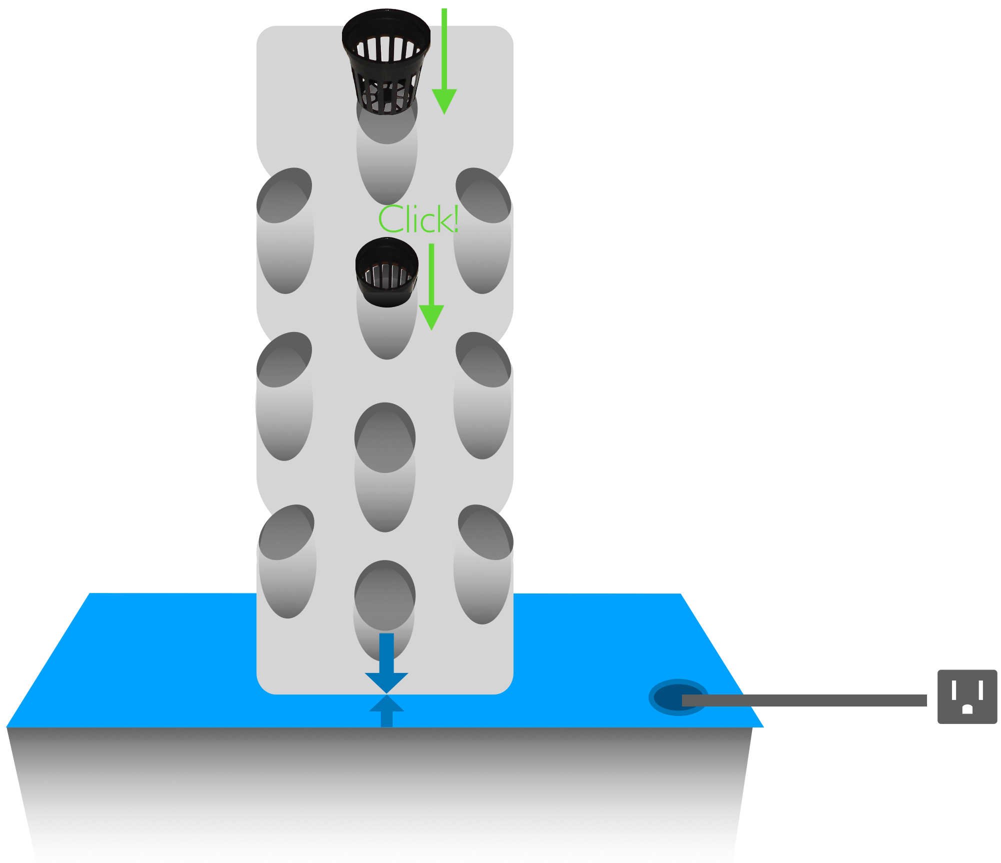
3. Attach the **sprinkler pipe** to the the pump through the threaded end and twist until secure.



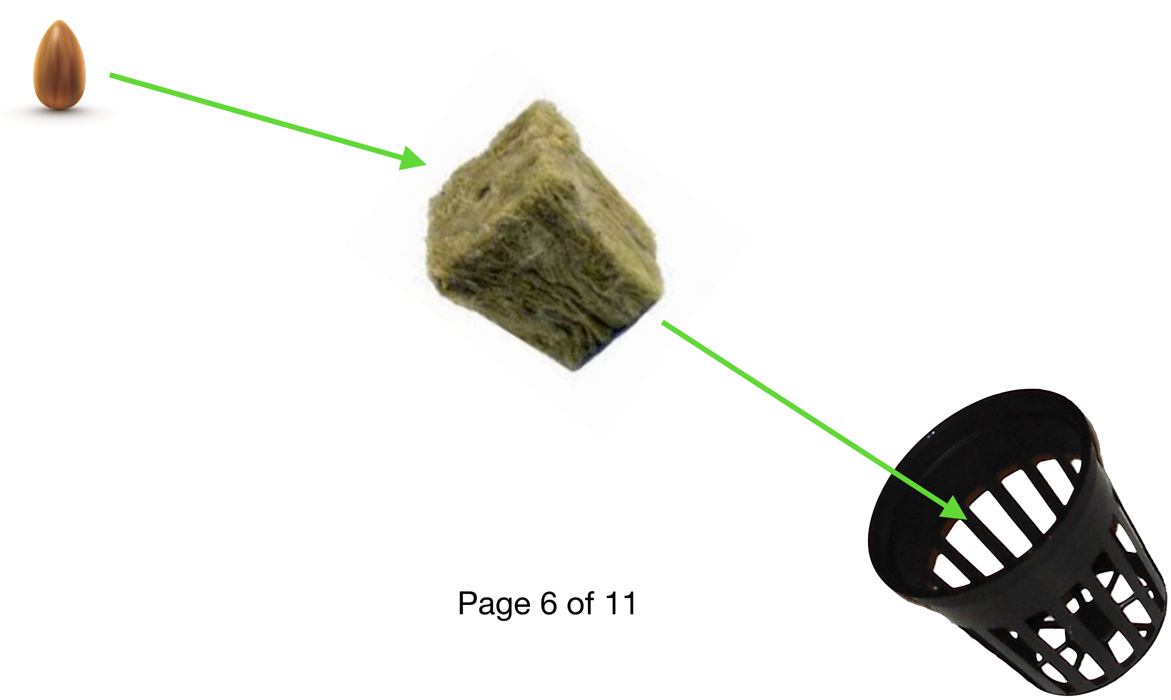
4. Secure the tower onto the base located near a bright window. This may require someone else's help. **Align** the blue arrow on the tower with the blue arrow on the base. Then, feed the **pillars** through the tower until the tower sits comfortably on the base. Note: the tower will still be able to move and sway, but will still stay upright.



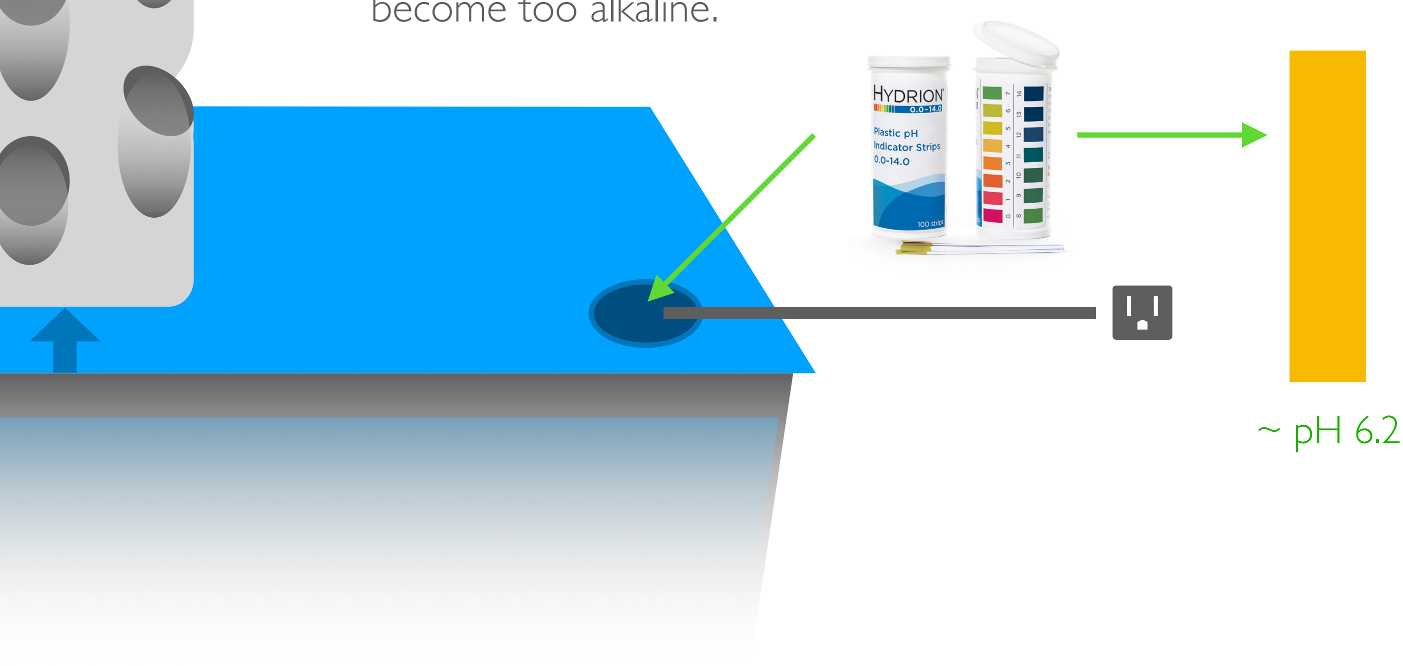
5. Place the **net pots** into each of the holes on the tower wall.



6. Plant the **seeds** into the **rock wool**, and place the rock wool into each **net pot** on the tower.



7. Fill the unit with water up to the designated fill line on the base.
8. Add in the right amount of nutrient solution according to the instructions listed on the bottle, and allow it to dissolve. The full capacity of the reservoir is 26 quarts.
9. Let the nutrient solution mix in, and test the pH using the **pH test strips** by dipping them through the **fill hole**. Ensure that the pH is as close as possible to pH 6.2 (which is slightly acidic, with neutral distilled water being pH 7.0). On most universal indicator pH test strips, a pH 6.2 is indicated by the color yellow.
10. If the pH is too high, add in a few drops of acid from either a lemon or some apple cider vinegar. Only add a few drops at any one time. Retest the pH each time to ensure that the solution does not become too acidic.
11. If the pH is too low, dissolve a small pinch of baking soda. Only add a small pinch at any one time, and allow it to dissolve. Retest the pH each time to ensure that the solution does not become too alkaline.



12. Setup the timer plug according to the manufacturer's instructions. When selecting the "on" segment, it is ideal to have the irrigation running for approximately 14 to 16 hours out of the day. Set this segment to your desired schedule.
13. Plug the unit in and watch it grow.
14. Regularly check the water level and add more water plus nutrient solution when the level gets low. Be sure to check the pH every time this is done according to steps 7 to 11 on the previous page.
15. In rare instances, certain plants can develop a condition called "nutrient burn" in which the edges of the leaves begin to brown over time despite having access to irrigation, due to the buildup of certain nutrients in the water supply. This typically occurs in units with low variety of plants. If this happens, jut drain the entire reservoir and refill with water and solution according to steps 7 to 11.
16. Sometimes, some seeds may fail to grow due to inherent defects. If you notice any seeds that are having trouble growing in comparison to others, just remove them from the rockwocl and re-plant the pod with a new seed.

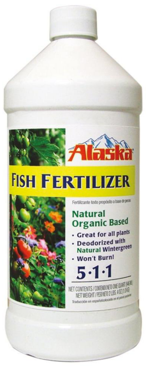
How Aeroponics Works

Seeds for the Aeroponix Tower System are started in natural rock wool fiber seeding cubes. The Aeroponix Tower System has a 26 quart reservoir at its base. This reservoir stores the nutrient solution and water supply. Inside the reservoir is a small, low wattage submersible pump. The pump draws the nutrient solution up through the center of the tower through a pipe and is sprayed on each plant pod.

From there, the nutrient solution is absorbed through the rock wool which allows the nutrient solution to feed the plant roots. As the water is sprinkled from the central tube, it becomes highly oxygenated and nourishes the plant's roots with all the necessary components for healthy growth.

This process is continually repeated, providing fresh oxygen, water, and nutrients to the roots of the plants. Because of the design of the Aeroponix Tower System system, the crops grow faster than they would in soil.

Vendor Information



You can find various types of nutrient solutions, seeds, and pH test systems at hardware stores such as Lowes and The Home Depot. There are many different brands of nutrient solution, and many of them work well. We recommend "Fish Fertilizer" by Alaska, which can easily be found at the Home Depot, but any good quality nutrient solution concentrate can work.
Any universal pH test strip will work for this system, and are widely available. We do not recommend any specific one.

For more information, visit:

www.homedepot.com
www.lowes.com

Special items such as rock wool, net pots, pumps, as well as specialized hydroponic and aeroponic nutrient solutions (for growing food, typically more expensive) can be found at San Diego Hydroponics and Organics. They carry an extensive selection of everything needed to build or maintain a hydroponics or aeroponics system. They have multiple locations around San Diego County.

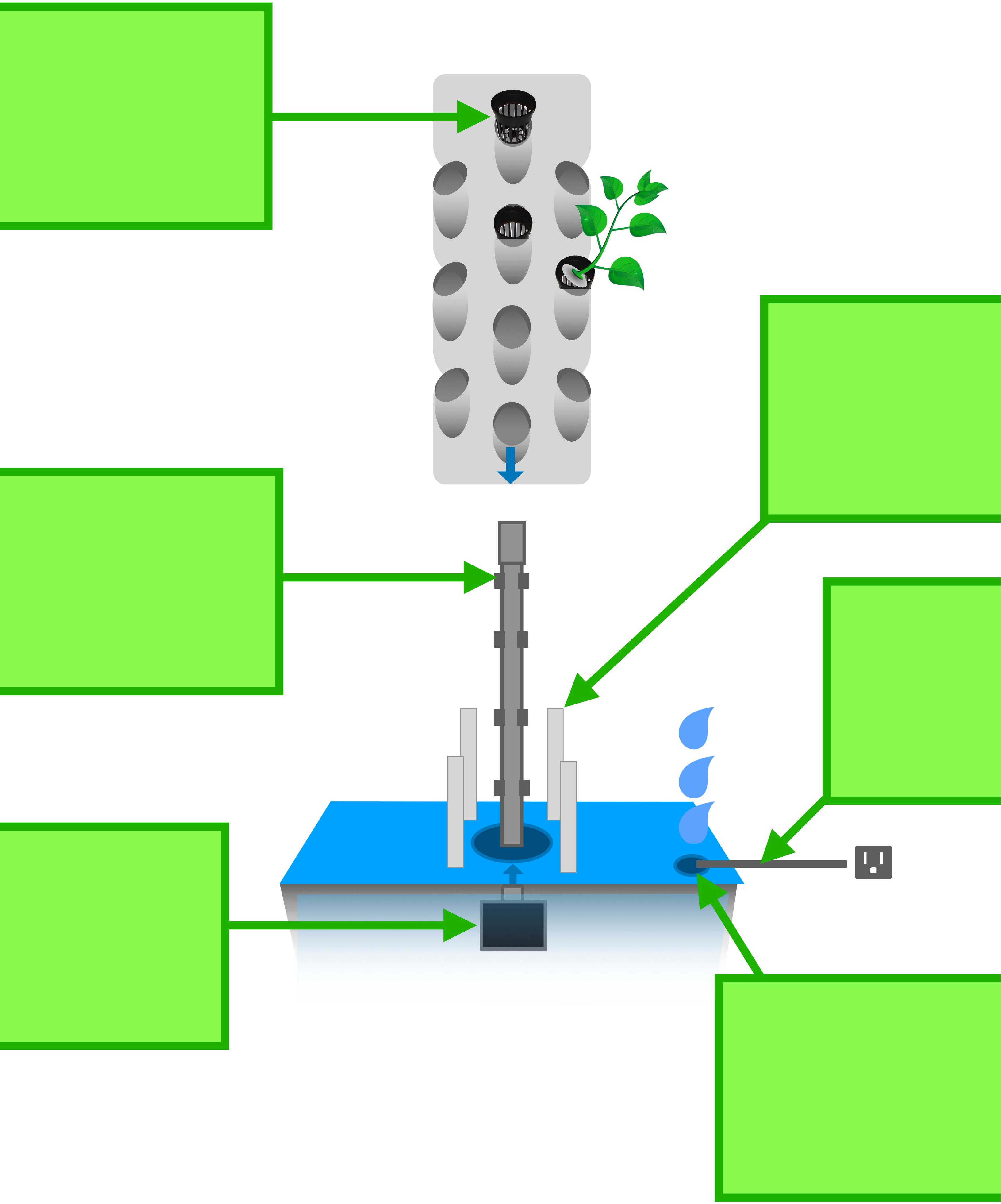
For more information, visit:

www.sdhydroponics.com

Contact Information

If you have any questions, comments, issues, or concerns, or need help troubleshooting any issues, please don't hesitate to contact Rasheed Al Kotob at (831) 224-7017 or at ralkotob@ucsd.edu.

Appendix 5: Printable Interactive Mix & Match Game



NET POT

SPRINKLER

PUMP

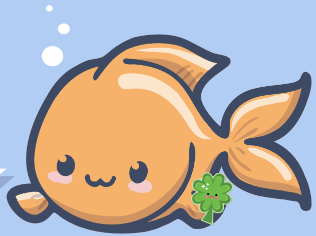
SUPPORT PILLARS

POWER CORD

WATER INPUT

Appendix 6: Interactive Educational Slide Deck

“Let’s Build a Garden!

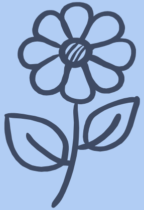


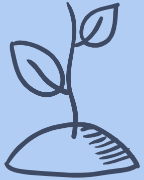
Appendix 6: Interactive Educational Slide Deck

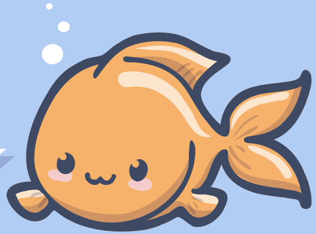
What is Hydroponics?

Gardening without soil

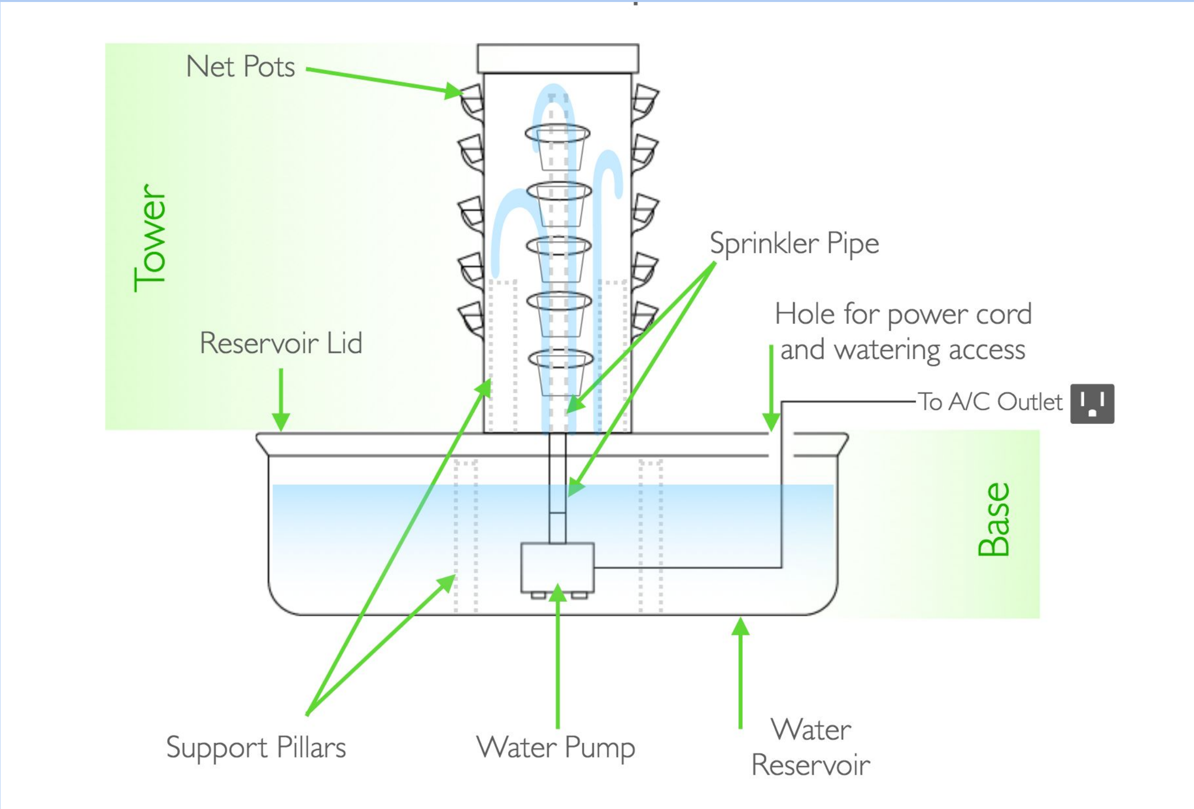
- Water
- Nutrients
- Light
- Oxygen

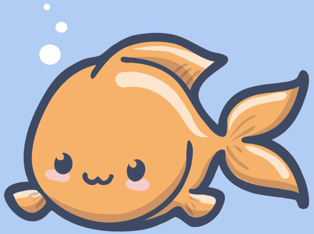




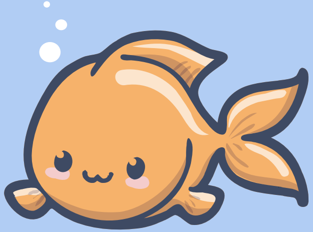


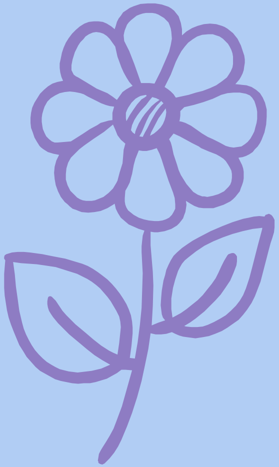
What's in Our System?



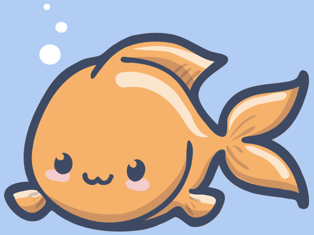


LET'S PLAY A GAME!





Work with your table group to connect your part to the description

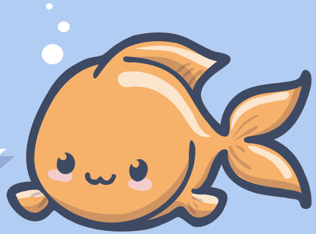


Our process is easy

plant

Water & Fertilize

grow



Thank you!