Aquaponics Art

A Senior Project

B.A. Liberal Arts and Engineering Studies

California Polytechnic State University, San Luis Obispo

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Project Overview

Introduction

Aquaponics

Aquaponics is a way of growing food that uses the wastewater from aquaculture (raising fish) to provide nutrients to plants growing hydroponically (in a soilless media). This combination not only provides nutrients for the plants, but simultaneously cleans the water for the fish to stay alive. The water is continually recirculated. The only inputs into the system are the water for refilling what gets evapotranspiration by the plants, energy to run the pump(s), and food for the fish. All of these inputs can be made renewable to create an entirely closed loop system operating on the power of the sun (Aquaponics Overview). Attention is increasing regarding aquaponics as our current agriculture practices are proving unsustainable in the long term (See "Modern Agriculture" in Lit. Review).

Aquaponics was first employed around 1000 AD by the Aztecs in the form of floating agricultural rafts in ponds. Later in the early 1970's, Dr. Mark McMurtry at the New Alchemy Institute developed modern aquaponics conducted in recirculating systems known as RAS or Recirculating Aquaponics Systems (Goodman).

PolyPonics Club

The PolyPonics club is the first aquaponics club at Cal Poly. Founded in the Spring of 2014 by Alex Hill and Dylan Robertson, PolyPonics club created Cal Poly's first Aquaponics system in Greenhouse F of the Crops unit. The 800 gallon system operates using Deep Water Culture Raft technology.

Figure 2: Cal Poly's first Aquaponics System in Greenhouse F of the Crops Unit

The Student Experimental Farm

The Student Experimental Farm (SEF) is a 2 acre site on Cal Poly's campus dedicated to exploring sustainable living. The site operated as a CSA under the title Cal Poly Organic Farm until 2010, when it shut down. After a period of time with not much student activity, the site is being opened up to students once again under the name "The Student Experimental Farm." I hope that the space can one day become a place for students to relax, escape the campus hubbub, and learn about sustainability.

Zion at the Student Experimental Farm

After construction and proven operation of Cal Poly's first aquaponics system in Greenhouse F, PolyPonics received enough money to construct a second system. For its location, the club chose the greenhouse at the Student Experimental Farm. The abandoned greenhouse space was dubbed "Zion" by PolyPonic's president Dylan Robertson. The club was given permission to begin constructing the second system. The second system is much larger than the first with a capacity of 2000 gallons, and the potential to expand. The second system currently uses Ebb and Flow style aquaponics, but will include more techniques in the future.

Figure 3: "Zion" at the Student Experimental Farm

Problem Statement

There is a lack of student involvement with PolyPonics club and the Student Experimental Farm.

From my personal observations, I have noticed that the Polyponics club has a problem attracting student attention to its aquaponics system in Greenhouse F. Although the system works wonderfully, there seems to be a lack of community knowledge about where and what it is. It is not operating at its full educational potential.

From other observations I also noticed a similar lack of student involvement with the Cal Poly Student Experimental Farm. The farm is a 20 min walk from campus, so getting people interested enough to make the trip up is part of the challenge.

I have also noticed that aquaponics is mostly unknown to the general public including Cal Poly students.

I understood that art can be tool to get people's attention and keep it (See "Art as an Attraction" in Lit. Review). I chose to use art as a main tool to bring people to the Zion SEF location and keep them there for longer periods of time. In addition, combining technology with art allows my project to act as a media through which aquaponics education and discussion can begin more readily (See "Aquaponics for Education" in Lit. Review).

My Project

My project is an aquaponics art installation that uses aquaponics technology to grow plants above a small pond.

My project engages Cal Poly students and San Luis Obispo community members with aquaponics in an interactive way. The project will first use aesthetics to capture attention, then provide all the necessary components for the participants to interact with and add plant to the art piece. Their involvement will be initiated by verbal guided direction, and their hands on contribution will hopefully leave a lasting impression in a way that passive observation cannot (Carlson, 1999, pg. 1).

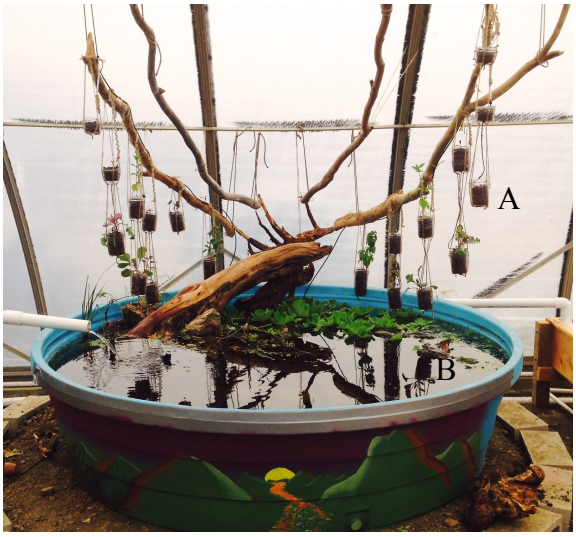

Figure 1: Finished Product

The project consists off multiple hanging aquaponics planters (A) suspended above a biofiltration pool (B) connected to the larger aquaponics system (C).

Those who visit the art piece will be allowed to engage with the system by planting a plant (A). Each planter will have the ability to removed and replanted in the system when the time comes to harvest, or if a plant dies.The system will be entirely automated. No watering or maintenance by the user will be required. This process will allow participants to choose a plant, plug it into the larger system, and return later to see how their plant is doing or harvest for food.

Literature Review

Modern Agriculture

The basic necessities of life include food, water, shelter, and medicine. There is substantial evidence that our modern agricultural system is unsustainable in a variety of ways. This means that our food security as a society is at risk.

According to Miguel A. Altieri from UC Berkeley,

> A growing number of people have become concerned about the long-term sustainability of existing food production systems. Evidence has accumulated showing that whereas the present capital- and technology-intensive farming systems have been extremely productive and competitive, they also bring a variety of economic, environmental and social problems (Altieri, 2000).

Farming at present is focused short term economics, but fails to take into account long term sustainability. The way we grow food excessively consumes resources that modern societies require including water, fossil fuel, and land. It uses them at a rate that is unsustainable for the practices to continue into the future. According to John Ikerd from the University of Missouri,

> [Agribusinesses] focus on the economic bottom line, which means they are managed to maximize short-run economic returns rather than long-run ecologic, social, and economic integrity (Ikerd, 2011).

Our current short sighted profit driven market has blinded investors from looking into the future. There is abundant evidence that our food production systems will need to drastically change in order to prevent extreme land degradation, maintain social order, and continue to survive as a species (Ikerd, 2011) .

Water Scarcity

One of the most pressing problems with industrial farming in California is a shortage of water resources. California is currently in the midst of a record breaking drought. Joshua Frank in an article from CounterPunch Magazine titled *The Crisis Over California's Water* states that, "The word 'drought' gives the impression that this is all short-lived, an inconvenience we have to deal with for a little while. But the lack of water isn't temporary, it's the new norm." (Frank, 2014). As the drought continues, farmers are increasingly drawing water from the state's ground water supply. According to a report by Janny Choy from Stanford:

> During droughts, surface water availability can be sharply reduced, leaving water users to pump water from local wells. At times like these, groundwater use can surge closer to 60% of water used statewide [from 30-40%], and even higher in agricultural areas like the Central Valley (Choy, 2014).

Groundwater levels are getting increasingly low and water is becoming a scarce resource very quickly. The same report later states that, "After more than a century of unregulated use, California's groundwater is in crisis...[California's groundwater is] used by 85% of California's population and much of the state's $45 billion agriculture industry". Much of water being consumed is by agriculture. According to the department of Air, Land, and Natural Resources farming accounts for some 80% of water consumed in California (Choy, 2014).

Due to a diminishing supply of water, it is clear that California must begin exploring alternative methods of growing food to save our remaining supply of groundwater and ensure food security into the future. One alternative method is aquaponics technology. Aquaponics provides a solution to many of the problems involved with industrial agriculture.

Aquaponics as an Alternative

Aquaponics has demonstrated a potential to increase the sustainability of our food production methods into the future. Aquaponics has numerous advantages over conventional farming. These include using less of a land footprint to produce the same yield of crop. Aquaponics can also be grown vertically to occupy the full volume of the growing space. Additionally, aquaponics does not need soil to function, so it can be done anywhere, regardless of soil quality or land availability. This means that aquaponics can be practiced in urban environments, localizing food production. This also means that aquaponics does not require as much fossil fuel for shipping produce to consumers. Additionally, aquaponics cannot function with the chemical inputs that conventional agriculture requires, as the fish would die. Therefore the system is always organic. Aquaponics also uses significantly less water than conventional farming (Why Aquaponics?).

The results of the beneficial attributes of aquaponics farming are explained clearly by M. Veludo in *Introduction to Aquaponics: A Key to Sustainable Food Production*:

> Key benefits of aquaponics over competing technologies are: food security, food health and safety (Ex: direct access to nutritious food in both urban and rural areas), reduced water use, reduced carbon footprint, reduced chemical use, reduced erosion of soils, and reduced need for land. Some believe that the role of aquaponics is going to be more important in the future given that our natural systems are forced towards increasing unpredictability. In fact existing production units have demonstrated that aquaponics permits the producer to be more efficient with water, energy, and to protect the crops from the elements. Furthermore aquaponics can bring a new approach to the sustainability of landscapes, urban agriculture and the sustainability of cities by turning wastes into resources and transforming disused urban spaces to provide not only food, but resilient communities. In addition, aquaponics has a high potential to revitalize cities and to create jobs (Veludo, 2012, pg.2).

The San Luis Obispo area is heavily affected by the drought, and is one of the few areas in California where residents are dependent upon groundwater resources (Choy, 2014). As the drought continues, groundwater levels continue to decrease as fights for water rights between farmers and residents are becoming more commonplace (Sneed). As this problem continues, the debate over how we use our water will linger if we continue to use conventional farming techniques to produce food that gets exported to other places. Aquaponics uses much less water than conventional agriculture (Aquaponics Overview), and provides a positive alternative for creating a resilient local food source.

Art as an Attraction

Getting people up to the Student Experimental Farm to see the second PolyPonics Aquaponics installation is the main goal of my project. To achieve this, I intuitively knew that making my project beautiful would be a very important component, if not the primary component. My intuitions were confirmed by the American Planning Association on their website:

> Arts and cultural activity can increase attention and foot traffic to an area, including attracting visitors and increasing the length of time and money they spend, thereby contributing to continued development. Similarly, the presence of public art and related streetscape amenities such as artist designed lighting, signs, and benches is a way to attract pedestrians (American Planning Association).

Nature is Psychologically Beneficial

As someone who tries to spend as much time in nature as possible, I recognize the intrinsic physical and psychological effects that it has on me. I notice that I feel more relaxed in nature, my mind calms, and after I am able to focus. These physical and psychological effects not only attract me to nature, but increase my ability to learn more new information. A study conducted by by Carolyn Tennessen et al. titled "Views to nature: Effects on Attention*"*comes to a similar conclusion. In the study, test scores of freshmen in dorm rooms with better views of nature are compared to those without views. Not surprisingly, those with views do significantly better. The basic theoretical premise is that nature acts as an attention distraction that allows the mind to rest, recover, and refocus (Tennessen).

Aquaponics for Education

Integration of STEM topics

A challenge with widespread Aquaponics implementation is that it requires technical knowledge. According to a paper titled, *Challenges and Opportunities for Aquaponics*, it is becoming apparent that the United States is lacking enough people with knowledge in the STEM fields to meet the sustainability challenges we are currently facing. The authors of the paper see Aquaponics as a useful technology for making self sufficient communities as well as for being

used as a tool in STEM education (Tamaru). Aquaponics utilizes knowledge from multiple fields, including engineering, biology, business, and more.

Perfect for Cal Poly

It is my belief that aquaponics provides the perfect context through which Cal Poly can begin to connect students from every college via the effort of making our food supply sustainable. US News ranks Cal Poly's Engineering and Agriculture colleges as some of the best in the nation (US News). Cal Poly has the academic potential, and aquaponics technology offers the technical solution. All that is needed is administrative support.

Art Can Be Used as a Tool for Learning

In order to make the concept of Aquaponics more commonplace, there is evidence that education can be enhanced through the use of art. In the foreword of *Learning in and through Art*, Eliot Eisner explains that:

> Discipline based art education... is a model that can serve the education interest not only of the arts, but of the sciences and social studies as well. It is as generous conception that lends itself to the adaptation to local circumstances. It is a conception that addresses a variety of outcomes, and it is a conception that demystifies what is appropriately demystifiable about the arts. *Learning in and through Art* can serve...those who work in other fields (besides the arts) and who care as deeply about the realization of other education ends (Eisner, 1998, ix).

In the case of aquaponics, using art presents unique opportunities to educate and inspire that may otherwise may not be as available.

Hands on Education

A hands on engineering program overhaul took place at CU Boulder in the 90's, changing the curriculum to be much more interactive, interdisciplinary, and education based. A report written a few years later indicates preliminary findings:

> Retention figures indicate that nearly 80% of students who took this course during their first year have remained in engineering into their third year, a remarkably higher rate than the college's 55% average. Students overwhelmingly report that this demanding
> design course gives meaning to their physics and calculus courses (Carlson, 1999, pg. 24).

Getting involved with this hands on project allowed me to apply my skills and knowledge to the real world . This would not have been possible without LAES. In an article titled *A Liberal Dose of Engineering* written in the Mustang Daily, the Cal Poly Liberal Arts Dean Linda Halisky is quoted stating,

> Even though you really, really have to be smart to get into Cal Poly engineering, we were losing a lot of engineering students...It is not unusual for engineering across the country, so it wasn't that anything was terribly bad here, but what was happening to all of these really good students ("A Liberal Dose of Engineering")?

When I was an engineering student, I had no time for anything but my theoretical studies. My hands on education began once I switched to LAES. I am thankful and grateful, and I hope that the completion of my project inspires others get involved in a hands on way at the Student Experimental Farm and with PolyPonics. Additionally, it is my hope that increasing hands on interaction with projects such as my own will enhance the educational experience of all who encounter it.

What Makes This a Liberal Arts and Engineering Studies Senior Project?

This project encompasses all the aspects that comprise a Liberal Arts and Engineering Studies project. The final product is a distinct entity that attaches to a larger aquaponics system, but can be evaluated separately. The success or failure of the project was on my shoulders alone, even though many people helped me. This project is grounded in theory and research to provides the basis for a creative technological art installation intended to solve the problem of a lack of interest in PolyPonics and the SEF.

Technology Overview

Selected Technologies

Aquaponics as a method of raising plants and fish together can be practiced with a number of different methods. For this project, I drew inspiration from two different hydroponics technologies; taking aspects from both to get the effect I desired for my project.

Windowfarms

The first of these technologies is Windowfarms hanging water bottle hydroponics planters. I selected this technology for its form shapeability, potential for interactivity, simplicity, and potential to look nice. I used the continuous flow style irrigation system from this design in my project (Windowfarms: About Us).

Hydroponics Art

The second technology I drew inspiration from was a hydroponics art project made by Amy Youngs. I was inspired by the way she used art to attract attention to hydroponics technology (Hydroponics Art).

I wanted my project to incorporate the best technological aspects of Windowfarms project, and apply them in an artistic way that simultaneously allowed for community engagement. In this way, I hope to inspire a sense of wonder and playfulness about aquaponics.

Being attached to the larger system, my project effectively bridges the gap between

consumer and producer. It invites people to see where their food is coming from, learn about aquaponics, and hopefully try it for themselves.

Design Ideation Phase

The Intention of this Project

The form of my project, the materials selected, and the technologies used were all informed by my goals regarding how I thought the project should function, how I hope people will interact with it, and how I hope it will progress into the future.

My project goals became apparent after I found out that PolyPonics would be moving to the Student Experimental Farm. Due to a perceived lack of student involvement with both PolyPonics and the Student Experimental Farm, I decided to make my project dedicated to increasing interest and involvement with Polyponics and the SEF. My intention was to promote PolyPonics, and create something of value for the Student Experimental Farm simultaneously. It became clear that the best way to do this would be to develop an aquaponics system that would create buzz on campus and throughout the San Luis Obispo community. In addition to creating excitement, it was my hope that my project would have the added bonus of increasing understanding about aquaponics simply through the design.

Once I had my intentions in place, I could begin with the design process.

To further elucidate how I would best go about making my intentions a reality through a constructed project, I started with a few broad questions:

Who will this project be geared towards?

My project is geared mostly towards Cal Poly students, but will also be seen by San Luis Obispo community members all with varying experience levels in aquaponics. My project should be both simple enough for those new to aquaponics to understand, and provocative enough for those more familiar to appreciate as well.

What will increase their interest in PolyPonics and the SEF?

Increasing their interest will be most easily done by catching their attention. This can be done by making aquaponics and the SEF exciting and eye catching. It can be done by educating people about the benefits of aquaponics. It can be done by giving people something to interact with while they are at the farm.

How can I increase their understanding of aquaponics through the form of a constructed engineering design project?

Increased understanding can be achieved by making the installation as simple as possible. Increased understand can also be achieved by providing meaningful interactivity and engagement with the technology. Both of these can be enhanced by being combined with art and different forms of education to inform, inspire, and increase competence.

How can I allow for and encourage meaningful community interaction with my project aimed at education?

Ideas for user interaction include having the user construct a portion or the totality of the project. Other ideas include having the user interact with the project once it has been constructed.

After asking myself these questions, I was able to get a vague idea about who my project would be for, and how it could conceivably accomplish my original goals. I then went into the more detailed design process to discover how to make these goals a reality through design, technology and materials selection.

What Makes this Project Unique?

Biofiltration Pool/Connection to Larger System

My project is unique compared to other vertical aquaponics and hydroponics systems because it attaches as a component to a larger aquaponics system. In addition, my project brings attention to and interacts with the unique biofiltration pool it hangs above. Most other aquaponics systems do not have this feature.

Education and Engagement

This project is unique because it educates, involves, and functions in an aesthetic way that speaks to multiple intelligences.

Function and Aesthetic

My design is unique compared to windowfarm hanging planters because it allows the planters and plants to be easily added and removed to and from the system. It also provides a natural and playful aesthetic that is lacking from most all aquaponics systems.

Scale of Application

My project is unique its scale, being bigger than most vertical planters and being integrated into an even larger aquaponics system.

Design Development Phase

Step 1: Developing a Vision

Coming up with an overall vision or theme for the project was a crucial first step that provided inspiration and will power to see it through to completion. I was initially inspired by the idea of hanging plants based on sheer aesthetic merit. As time progressed, I began to see that the hanging planters could be played with to create different effects. I tried different shapes and arrangements to get a feel for the message they would convey.

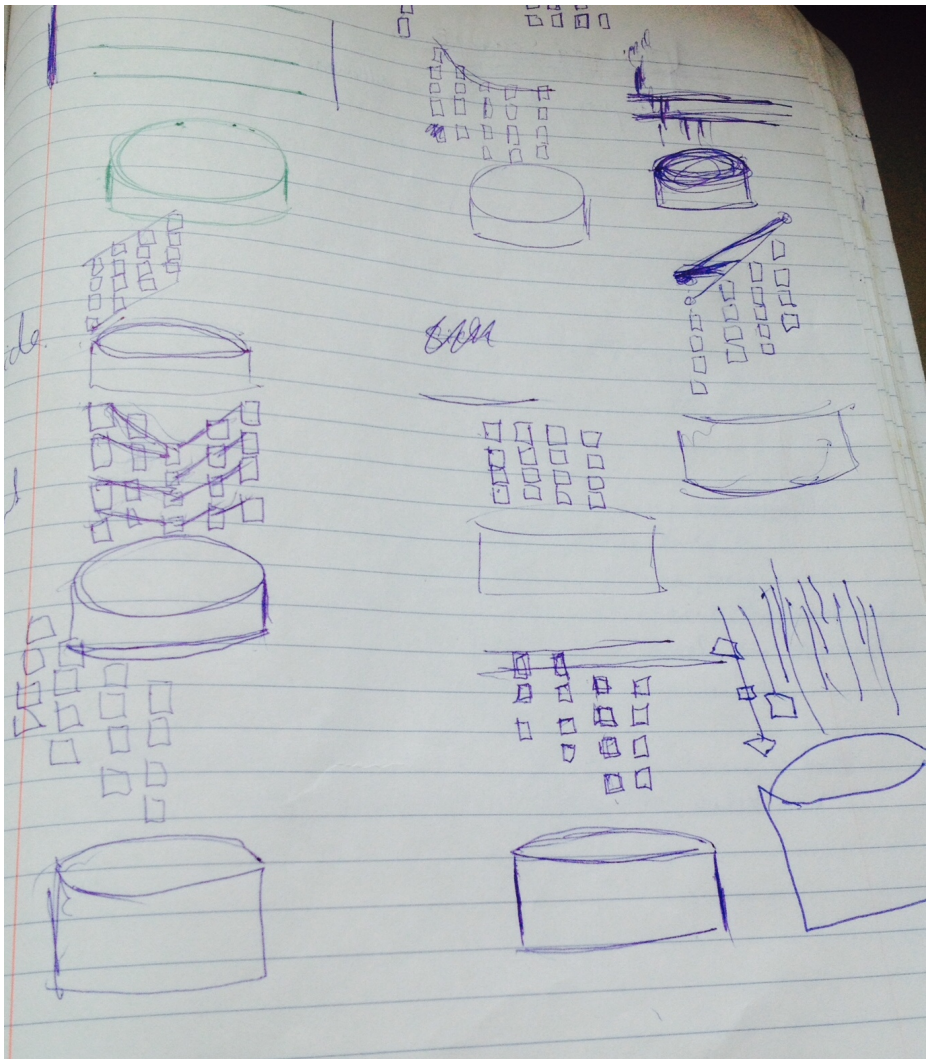

Figure 4: Hanging Design Iterations

After playing with many different possible shapes, I decided that I liked the idea of a dome, or chandelier the best. I wanted people looking at the piece to feel enclosed and comforted

by the structure. As if they were standing underneath a tree. I thought this would intuitively catch peoples attention as a recognizable form.

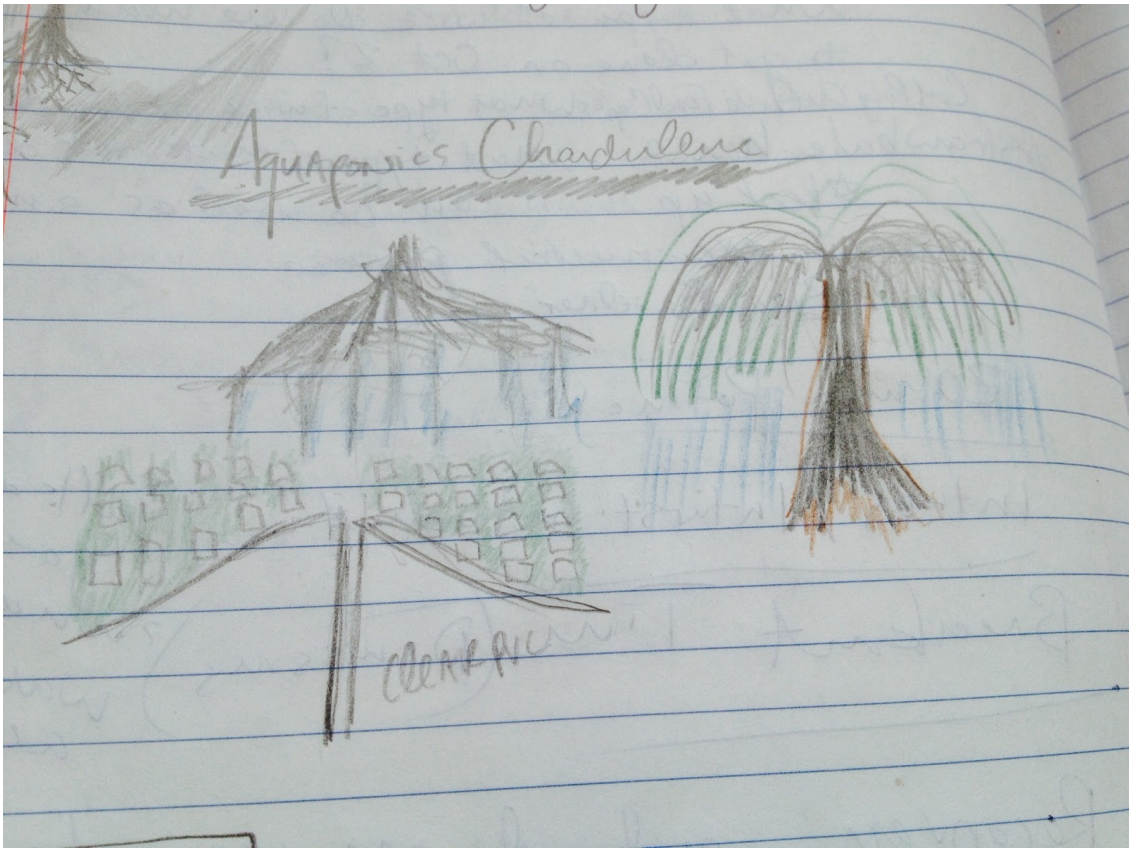

Figure 5: Tree Concept Design

I began thinking of ways that I could mimic a tree, while retaining the feel of a chandelier, and integrating this concept together with aquaponics for aesthetic, and community engagement.

Keeping the middle area over the pond open gave the structure a more spacious feeling, and kept my original inspiration to make a hanging plant chandelier without having a tree trunk in the middle of the pond.

Considering community engagement as a factor, I thought that having the planters closer to the edge of the pool would allow for easier access.

These coinciding factors led me to look at the Willow Tree for inspiration.

Figure 6: Willow Tree

Space Constraints and Limitations

Dylan, the PolyPonics president, had the original vision of the Zion aquaponics facility as a space completely filled with experimental aquaponics techniques. Knowing that he planned to expand the system using the floor space, I chose to use the vertical space. After talking more with Dylan, I learned that the Zion system was unique in that it used biodiversity as a component; something that commercial aquaponics has not done up to this point. The biodiversity of the system is exemplified by the central pond that will have many species of fish and aquatic plants. Having biodiversity in the system increases resilience in the case of unexpected environmemntal changes (ex. cold weather). I wanted to bring attention to this unique feature, as well as make use of it as an already existing, aesthetically appealing, and highly visible component of the system. For these reasons, I chose to construct my project in the vertical space above the central pond.

Figure 7: Biofiltration Pool Yin Yang

The pool occupies a circular footprint 112'' across in diameter.

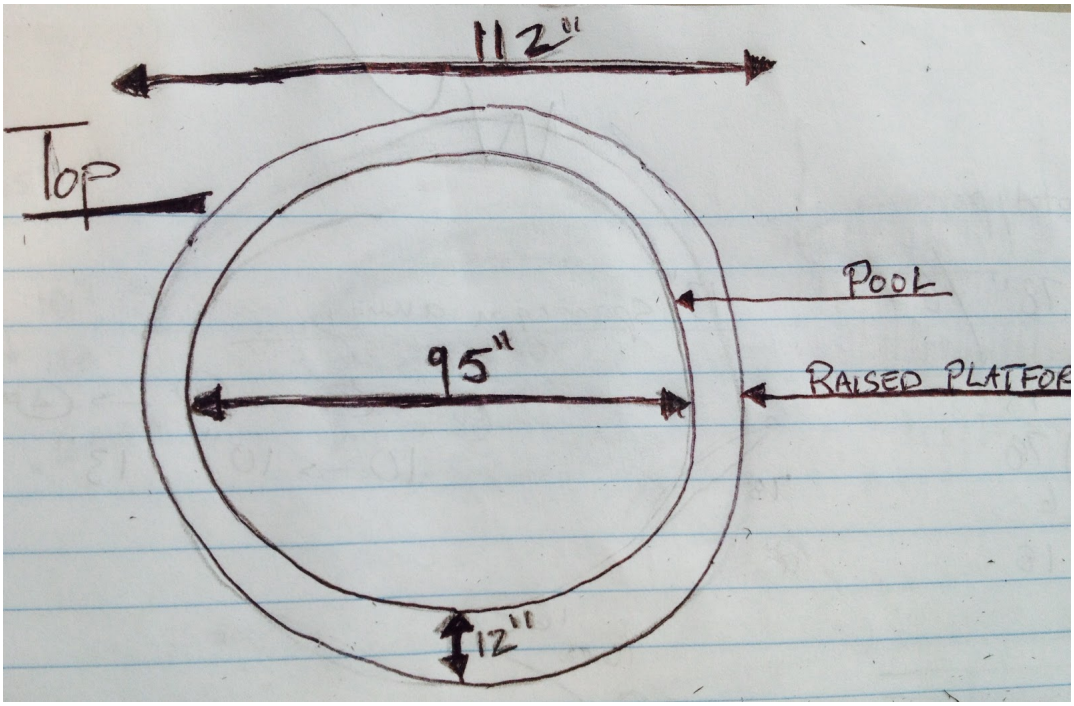

Figure 8: Biofiltration Pool Top View

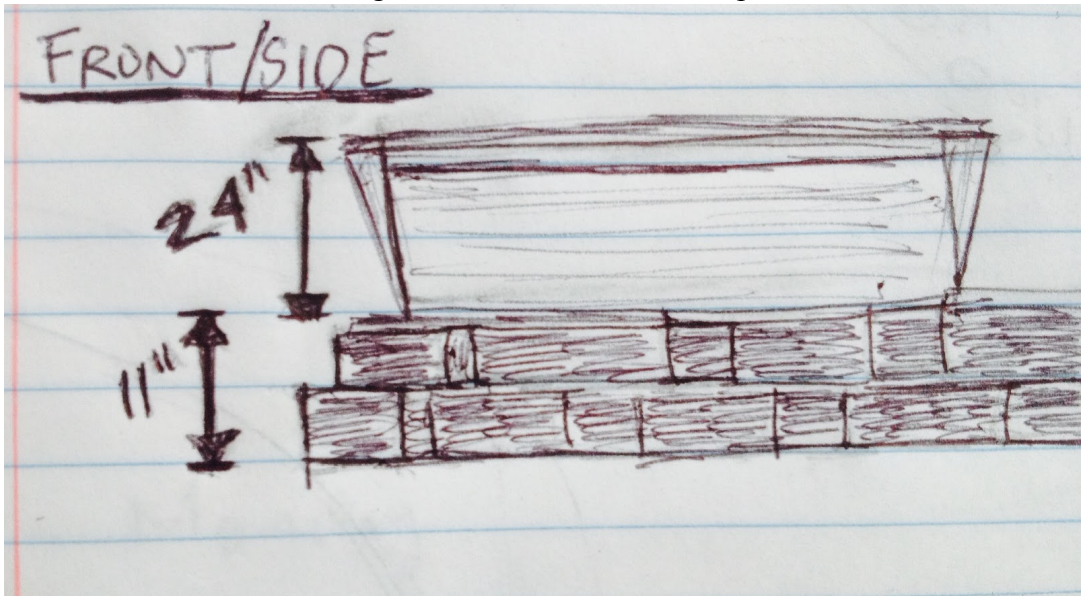

Figure 9: Biofiltration Side View

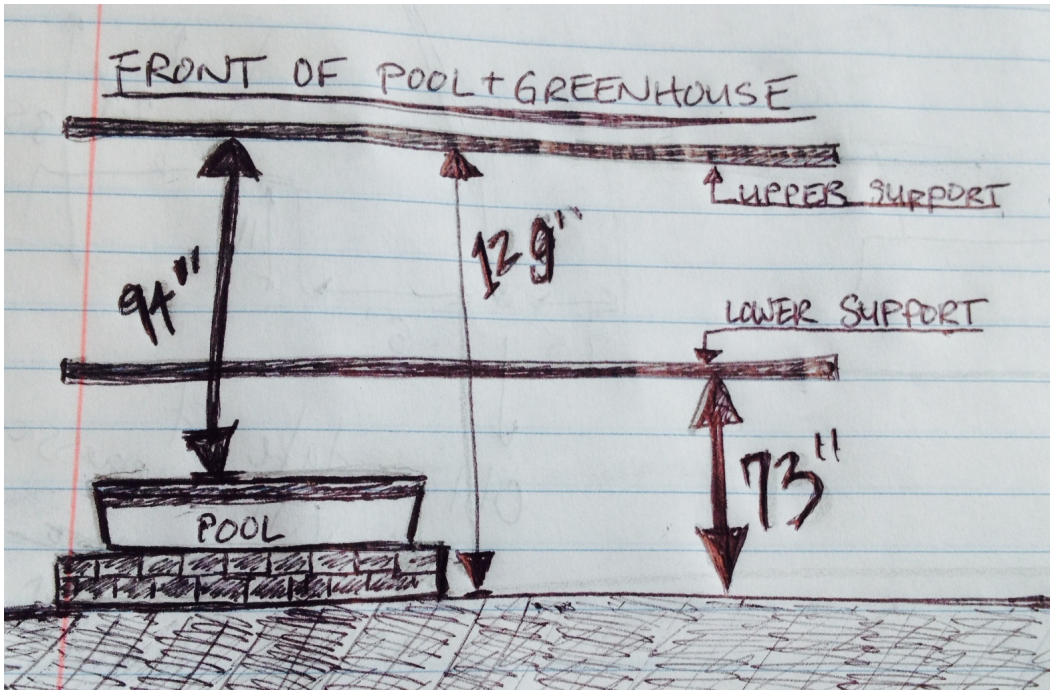

Figure 10: Biofiltration Pool Side View II

The pool has a vertical space ranging from 39'' -94''.

Other Limiting Factors

Other factors beyond space limitations were considered in the selection of the site. Power for running any sort of pump was readily available for use in the this greenhouse. Shelter provided by the greenhouse creates a warm environment protected from rain and cold weather to keep the nutrient water from getting diluted, and the plants alive. Abundant sunlight from the San Luis Obispo sky is all the light that will be needed to grow plants in this system.

Once the spot for my project was selected with all physical limitations known and documented, I was able to begin selecting materials and begin construction.

Materials Selection and Construction

Step 1: Selecting Planter Technology
Step 2: Envisioning and Constructing Frame
Step 3: Hanging the Frame
Step 4: Selecting Planters
Step 5: Prototyping Hangars
Step 6: Making Hangars, Drilling Mason Jars, and Hanging
Step 7: Irrigation

Step 1: Selecting Planter Technology

I started this project with the idea of using Windowfarm technology as a media for community engagement with aquaponics. After a semi failed test run where I had little kids make their own planters, I changed the direction of my project to focus more on aesthetics than community interaction. It just so happened that the Windowfarms style of hanging planter worked perfect for my concept of a tree dome/chandelier. I was already familiar enough with Windowfarms to know it was adaptable and modular enough to do what I wanted with it; so I had at least one option to make my vision a reality.

Further evaluating different technologies in the areas of aesthetic, simplicity, cost, and interactivity allowed me to see more clearly that I was already using the right technology.

Windowfarm Technology

Figure 11: Windowfarms Bottle Planters

Aesthetic

Having individual hanging units allowed me to arrange the planters how ever I wanted without regard to the structure they would be hanging from. The planters are small and not bulky in scale, and can be made to look nice out of anything as long as there is enough room for plant roots.

Simplicity

I was originally attracted to this technology because of its extreme simplicity. I thought it was genius to boil down hydroponics to its fundamental components to function in a very

obvious and visible way. It was my hope that the simplicity of this technology would allow users to more easily understand aquaponics.

Interactivity

Due to this technology's simplicity, I was able to see it's potential for user interactivity. I believe that there is a direct correlation between simplicity, modularity, and the potential for interaction. Windowfarms was the simplest hydroponics system I could find, and its modularity lent itself to interactivity.

Cost

The cost of this system can be next to nothing if one is able to obtain water bottles, growing media, a water pump, tubing, and plants. That is all that is needed with most of the cost being incurred from the pump.

Step 2: Envisioning and Constructing Frame

After starting with the initial idea to use hanging planters in some formation, the next question was what they would hang from.

I began with a rough prototype frame made from scrap PVC to get a feel for what would work best.

Figure 12: Hanging Structure PVC Prototype

Hanging the PVC pipes revealed to me that users would not be able to reach the planters hanging in the middle of the pool. I changed up my design concepts to focus on making the frame hang over the edge of the pool. I was still focused on the development of a dome chandelier shape with the overall aesthetic being reminiscent of a tree

Frame Material Selection

After trying my PVC prototype and realizing that I needed to change the design of my structure, I began exploring other options that had the frame closer to the edge of the pool.

I started with BuckMinster Fuller domes. I was seduced by the concept of making a portable, mobile structure. I thought that it would be very cool to make a collapsable dome that could be moved from place to place to showcase aquaponics. After much struggle and debate, I abandoned this idea to simplify the scope and amount of work of my project back to a single, simple application for PolyPonics.

Next in my design test phase, I turned towards scrap metal tubing that was already available at the SEF to mimic what I had previously built with the PVC tubing. The metal tubing was bent in a perfect U shape that fit the contour of the back half of the pool. After much waiting and evaluation, I couldn't get myself to begin construction with the metal pipe. It simply didn't look good enough.

I returned to my original vision of a tree chandelier, and got the idea to use sticks. After hunting around for some suitable sticks, and arranging them towards the edge of the pool; I felt I had found what I was looking for. I left the sticks in place as the "branches" of my tree. Additionally, the eucalyptus branches are resistant to rotting.

Step 3: Hanging the Frame

Figure 13: Wood Frame with ½ of Planters

To figure out how to hang the frame, I started as simple as possible, and eliminated my options from there. The simplest solution was to use rope. I found a synthetic rope that could support much more than the weight of my project, looked nice, and was easily set up. I had considered using hooks, or chains; but I felt that the simple aesthetic of the rope worked the most cohesively.

Step 4: Selecting Planters

After consulting with James Werner in the Art department, I concluded that the planters in my project were central to the design and aesthetic. In particular, I concluded that I should be focused on the aesthetic of the planters as individually and collectively interesting and beautiful.

Taking the simplicity of windowfarms and changing the planter to something more beautiful was an easy step to adding aesthetics to an already interactive and simple technology.

I did a decision matrix to decide what to make the planters out of between squash gourds, bottles, mason jars, etc. In the decision matrix I compared toxicity, ease of hanging and putting holes in bottom, breakability, obtainability, aesthetic, and sustainability.

Note: The final scores in this matrix are slightly inaccurate in reference to their actual total score.

Figure 14: Bottle Selection Decision Matrix

My decision matrix left me with a choice between squash gourds, clay pots, ceramic mugs, and mason jars. Water bottles got eliminated in this process for fear of water contamination after exposure to UV light. Squash gourds proved impossible to find, and were subsequently eliminated. Ceramic pots and mugs were tested, but both lacked the aesthetic appeal that the mason jar had. The mason jar was the most solid aesthetically, but lacked a hole in the bottom for water to come out.

This led me to my next step of trying to get mason jars to work by drilling a hole in the bottom. After consulting with the art department shop manager, I was able to borrow his diamond tip drill bit to get the job done.

Figure 15: Mason Jar with Hole in Bottom

Step 5: Designing and Prototyping Hangars

After choosing my planter device, the next step was choosing how to put them all together. I wanted to put them together in a way that users could take one planter out of the system, and replace it with another. To figure out the best way to do this, I considered various options including velcro, mesh pouches, tapered plastic cups, and elastic bands. Rating them in the areas of function, obtainability, aesthetic, setup, and cost; I was able to conclude that using elastic mesh, or velcro would be my best bet.

Figure 16: Hanging Planter Decision Matrix

I purchased a number of different materials including elastic, twine string, chicken wire, and different kinds of metal wire. After my purchased I made prototypes to figure out what would work and look the best. Beige twine looked better than elastic or velcro.
Steel wire functioned the best out of all the options, but looked better when combined with the twine. After many iterations of different hangars I settled on using chicken wire and twine together to form quad-stringed hangars that the mason jars would sit inside of like a little home. The strings come together underneath the jars connecting to a steel ring.

Figure 17: Plugging in Mason Jars to Hanging Planters

Step 6: Making Hangars, Drilling Mason Jars, and Hanging

The next step in the process included replicating the hangars that I previously mentioned. Sizing the hangars to fit properly on the hanging branches was important to the overall aesthetic. Drilling the all the mason jars was done with a diamond drill bit and a drill press in the Bonderson Lab. Hanging the planters was done by drilling holes in the branches to keep the string tie in place and avoid slipping.

Step 7: Irrigation

A small fountain pump on a timer based water up into this tubing, which splits into two standard ¼'' ID irrigation tubes running up each branch. 1 GPH drippers come off the end of the line at the top of each column into the top jar. Everything was put together using standard tee splitters and tied to the branches using the same twine for than planter hangers.

Figure 18: Wrapped Clear Irrigation Tube with Micro Emitters and Wicking Twine Out the Bottom

Figure 19: 1-4’’Black Irrigation Line Running up Branch

Figure 20: Completed Structure Without Plants

Step 8: Painting

Once everything was constructed and hooked up, painting of the pool could begin. For this step, I worked closely with my friend Dede Eckhart to turn my vision of rolling San Luis Obispo hills into a reality.

Figure 21: Painted Pond

Step 9: Adding to the Pond

With the structure set up and the pool painted, I could begin adding to the pond. A member of the PolyPonics club named Erik (pictured above) who has a lot of experience with aquariums took charge of the pond area. Together we created and execute a vision for the pond, which included a tree trunk base to bring together the aesthetic of the pond with the hanging branches. These two components worked together to finalize my vision of a tree dome with the ability grow food.

Figure 22: Planted Structure and Pool (Left Side View)

Figure 23: Planted Structure and Pool (Right Side View)

Step 10: Planting

The final step of my project once water was flowing, the pool was painted, and all the irrigation was hooked up was to plant the plants! This involved taking plants out of soil, removing dirt from their roots, and planting the roots in the lava rock filled mason jars. Now with everything in place, the project was complete and now ready to grow plants automatically.

Analysis and Verification of Project Success

The criteria for success for this project was unique to the time and place that it was being conducted. Some of the criteria for success were based on a simple yes or no, some quantitative metrics, and others through qualitative opinion collection.

A survey was conducted after having an aquaponics workday in which participants who were there that day were asked what their opinions of my project were. The survey provided space for both free response and Likert 1-5 scale ratings. The survey can be referred to in Appendix A of this paper.

I developed the criteria for the success of my project based on my project goals:

Factor 1: Completing the Project
Factor 2: Adding aesthetic value to the Zion aquaponics system
Factor 3: Increase People's interest in Aquaponics
Factor 4: Increase People's interest in the Student Experimental Farm

Factor 1: Completing the project

This factor will be evaluated using a checklist with step functions of 10% for determining total completeness. In order for my project to be complete I must have done the following:

Purchase/Obtain all Materials (10%)
Construct Frame (10%)
Hang Frame (10%)
Build all planters (10%)
Hang all planters (10%)
Drill Holes in Mason Jars (10%)
Hook up irrigation (10%)
Fill planters with Rocks and plants (10%)
Get timer functioning, irrigation flowing (10%)
Plants continuing to live and grow (10%)

Figure 24: Project Completeness Evaluation **Areas of Incompletion

Factor	**% of Factor Complete**	**% Accounting for Total Project**
Purchase/Obtain all Materials	100%	10%
Construct Frame	100%	10%
Hang Frame	100%	10%
***Build all planters	50%	5%

**Hang all Planters	50%	5%
**Drill Holes in Mason	50%	5%
Jars Hook up irrigation	100%	10%
Fill planters with Rocks and plants	100%	10%
Get timer functioning, irrigation flowing	100%	10%
**Plants continuing to live and grow	0%	0%
Total	------	**75%**

Breaking down my project into components allows me to see that I accomplished the majority of my original vision, but that some parts were left incomplete (**). I will now go into further analysis of why each component got scored the way it did.

Purchase/Obtain all Materials (10% of total)

I fully purchased and obtained all the materials that I need in order to execute my full original plan.

Construct Frame (10% of total)

I fully constructed the frame to be used for hanging planters. (100% score)

Hang Frame (10% of total)

I safely hung all the components of my frame from the rafters. (100% score)

****Build all planters** (10% of total)

I made a little more than ½ of the planters I originally intended to make, so I gave myself a score of 50% for this component. (50% Score)

****Hang all planters** (10% total)

I was not able to complete all the planters for my project, and this carried over to reduce the score for this category as well to 50%. (50% Score)

****Drill Holes in Mason Jars** (10% total)

I drilled almost all the holes in the mason jars that I would need to complete my score) project. (550% Score)

Hook up irrigation (10% of total)

I was able to completely hook up my irrigation system including a pump, timer, irrigation

line, and drippers. (100% score)

Fill planters with rocks and plants (10% of total)
I was able to completely fill all planters that were complete. (100% score)

Get timer functioning, irrigation flowing (10% of total)

The irrigation was completed and flowing, providing potential plants with water and nutrients 8 times a day. (100% score)

****Plants continuing to live and grow** (10% of total)

At the time this paper is being written, it is yet to be seen how well plants stay alive, so the success of this factor will be determined once all the planters are filled, and more time progresses. For now, the success of my project determined by this factor remains unknown. For this reason, I am left with no option but to give myself an incomplete (0%) for this part. (0% score)

Adding up all the components for this factor leads me to give myself a score of 75% for my project completion.

Factor 2: Adding aesthetic value to the Zion aquaponics system

This factor was determined by the opinions of those that participated in my survey. Their feedback was both qualitative using a free response method, and quantitative in measuring how much they felt it added to the space.

My survey was taken by 8 participants whose aquaponics expertise ranged from "very little" to "expert". Most fell somewhere in the middle of these levels of expertise.

In my survey, I asked the participants who had seen the mostly complete version of my project the following free response question:

Do you feel this has added or subtracted aesthetic value to this aquaponics facility? How?

The following are responses from the participants:

"It has added to the aesthetic tremendously bringing a full breadth of dimension to the two dimensional system currently set up in Zion."

"Most definitely added. It is a creative and efficient piece of art."

"It is the focal point of the project and has potential to develop into something beautiful once the plants grow."

"Yes, I believe it added a delicate natural beauty to the aesthetic of Zion (among all the hoses and pipes). A play on light and shadows, one can ponder its meaning throughout different stages of the day. Really adds volume to the space in zion- high ceilings, but

oftentimes visitors look at what's in front of or below them. Take someone who's never been in there before, let them walk in, and watch as their head tilts up and around to view the aesthetic of the "hanging aquaponic planter"-- is there another name for that?"

"It has added because it looks amazing and the aquaponics facility is all about ideas and experiments. it is a great idea and will look really good if plants actually grow in the jars."

"I feel that it adds to to facility because the branches and jars give a nature feel to the greenhouse"

"The mason jar installment has significantly improved the aesthetic quality at the aquaponics facility. Before it was just a plastic tub with some dirty looking water and a few nice but empty grow beds when I saw it. Now it is very artsy, a simple yet elegant natural design."

"This installment has added aesthetic value to the facility because of its natural look. Its the perfect combination of functionality, because it uses vertical space to produce food, and art. This project is one of my favorite things in the facility. It makes the aquaponic system look less like a factory and more like something you would want to see in your backyard."

I was overwhelmingly satisfied with the responses I got, and it makes me happy to know that people appreciate my project and feel it adds value to the the aquaponics system.

Factor 3: Increase People's Interest in Aquaponics

This factor was determined by quantitative data collected in my survey. Note that those surveyed were already at the space for an aquaponics work day, so their interest levels are most likely unusually high. But, I assume in the future that most people coming to see the aquaponics facility will have at least some inkling of interest in aquaponics. I asked them to respond using a Likert scale of 1-5 [5(strongly agree) 4(agree) 3(neither) 2(disagree) and 1(strongly disagree)] how much they agreed with the following 3 **bolded** statements:

Statement 1: Prior to attending this exhibit, I was interested in Aquaponics.
Their response data is as follows:

Figure 25: Prior Interest Levels in Aquaponics

Response Rating	Number of Responses
5-Strongly Agree	4
4-Agree	4
3-Neither	0

2-Disagree	0
1-Strongly Disagree	0
Average Score of Totals	4.5

This data tells me that the level of interest in aquaponics was very high among the group of students surveyed.

Statement 2: After attending this exhibit, my level of interest regarding aquaponics has increased.

Their response data is as follows:

Figure 26: Interest Levels After Visiting My Project

Response Rating	Number of Responses
5-Strongly Agree	5
4-Agree	2
3-Neither	1
2-Disagree	0
1-Strongly Disagree	0
Average Score of Totals	4.5

This data indicates that the average participant in the survey felt this this installation had increased their levels of interest in aquaponics. This is a surprising result to me considering the participants already knew what aquaponics was. This suggests that they were interested in the way that it aquaponics had been used for an art piece, rather than in the concept of aquaponics itself. My guess is that people unfamiliar with aquaponics might respond differently, as their increased levels of interest may be a result of learning about the technology itself.

Statement 3: After attending this exhibit, I am more likely to involve myself with aquaponics in the future.

Their response data is as follows:

Figure 27: Likelihood of Future Aquaponics Involvement

Response Rating	Number of Responses

5-Strongly Agree	3
4-Agree	4
3-Neither	1
2-Disagree	0
1-Strongly Disagree	0
Average Score of Totals	4.25

From this data, it is apparent from their responses that they felt they would be more likely to involve themselves with aquaponics into the future. Their response data put them on average in the area just beyond agreeing that they would be more involved.

From the responses I received, I can only make the following conclusions:
On average the participants were interested in aquaponics prior to seeing the exhibit.
Seeing the exhibit still had the effect of increasing their interest levels in aquaponics.
Seeing the exhibit made made it more likely that they would participate in aquaponics in the future. Considering that the initial intention behind my project was to increase interest and involvement; I am deeply satisfied that even people who knew about aquaponics felt more interested, and that they would be further involved in the future.

Factor 4: Increase People's interest in the Student Experimental Farm

This factor was determined by the quantitative data collected in my survey evaluating the participants interest in the SEF both before and after visiting. I asked them to respond how much they agreed with the following statements using the same Likert scale of 5(strongly agree) 4(agree) 3(neither) 2(disagree) and 1(strongly disagree):

Statement 1: After attending this exhibit, I am more likely to involve myself with the Student Experimental Farm in the future.

Their response data is as follows:

Figure 28: Likelihood of Future SEF Involvement After Visiting My Project

Response Rating	Number of Responses
5-Strongly Agree	3
4-Agree	4
3-Neither	1

2-Disagree	0
1-Strongly Disagree	0
Average Score of Totals	4.25

From the data, the people who took the survey said on average that they would be more likely to involve themselves with Student Experimental Farm. Only one respondent reported that they would neither be more or less likely to spend time at the farm. Keep in mind that most of the individuals who took the survey already had been to the farm previously, and had an interest in it. Still, their responses point towards a theme of my project increasing interest in the locale that I chose to construct it.

Statement 2: After attending this exhibit, I am more likely to consider creating project of my own at the Student Experimental Farm.

Their response data is as follows:

Figure 29: Likelihood of SEF Project Creation After Visiting My Project

Response Rating	Number of Responses
5-Strongly Agree	3
4-Agree	5
3-Neither	0
2-Disagree	0
1-Strongly Disagree	0
Average Score of Totals	4.38

The data indicated that every one of the participants agreed that they felt more likely that they would create a project of their own at the Student Experimental Farm. This is an inspiring conclusion to draw because it means that the creation of one project inspires the creation of many more. If this trend holds true, growth of student involvement with the SEF will be exponential as more people find out about it and begin to get involved.

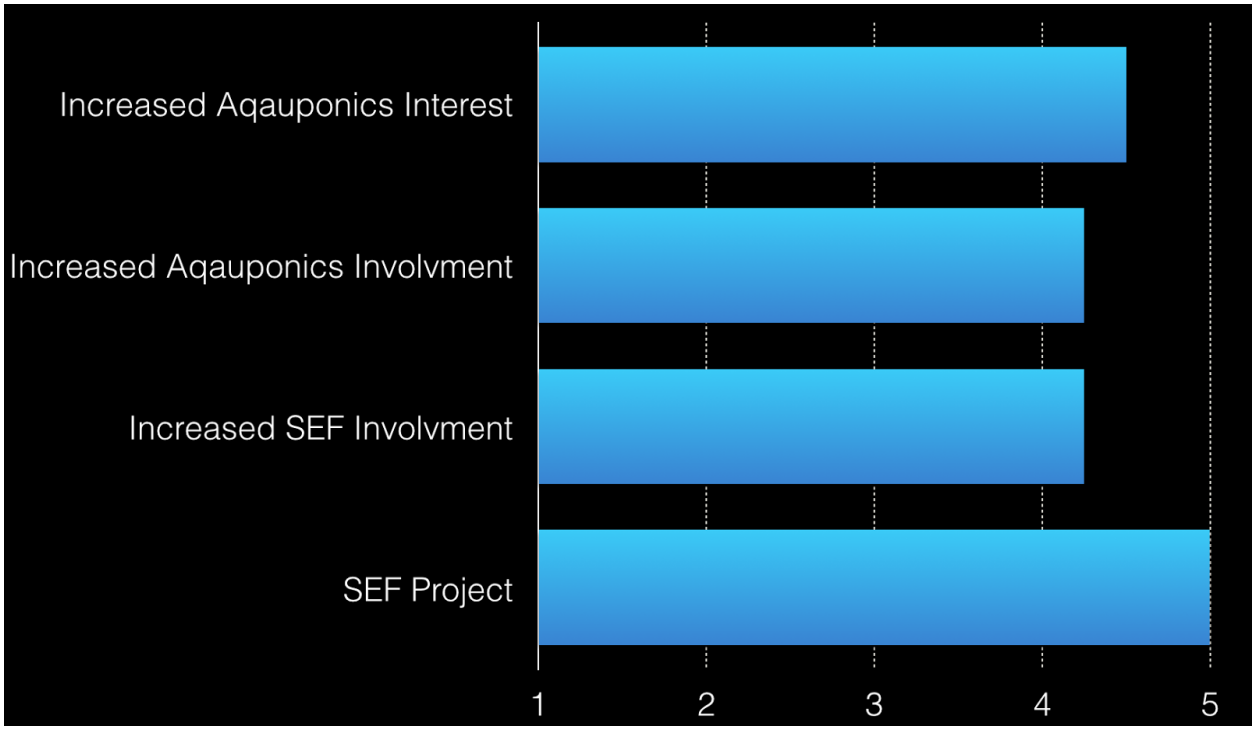

Figure 30: Level of Agreement to the Survey Statements

This chart shows the level of agreement to the above statements compared to one another. It is apparent that there is not much difference between the categories, although the categories that had the most agreement among the participants included them having an increased interest in Aquaponics, and an increased likelihood in doing a project at the SEF

From the responses of these two questions, I feel my project can be claimed successful at creating more interest in the SEF, and increasing potential for future student involvement. I am excited by the prospect of the Student Experimental Farm become a sustainable technologies hub on campus, and I hope my project can play a positive role in the creation of that reality.

Societal impacts

I have high hopes for my project as a living, growing piece of art that will potentially attract more interest in aquaponics and the Student Experimental Farm. By increasing interest and engagement amongst Cal Poly students, my hope is that Aquaponics knowledge will be transmitted to an increasing number of educated individuals across California. The potential benefits of educating people to have knowledge in this area include localizing food systems, creating jobs, and saving resources to create more resilient communities across the state.

In addition I hope my project helps enhance the educational experience of Cal Poly students by demonstrating the potential of the Student Experimental Farm as a place of hands on learning, experimentation, and exploration into sustainable technologies. According to Vandana Shiva; the outcome of the problems we currently face as a society will be dependent upon how many people we have on the land acting as conservers (Shiva). The more students we can get outside the classroom to begin applying their ideas to a real world environment, the better chance those ideas have of becoming a reality. I hope my project can play a role in revitalizing the SEF as a place filled with real life visions of a better world.

Future Work

Future work for my project includes enhancing the process behind getting the students to interact with it and plant their own plants. Currently, there is nothing prompting them to do so except for people already at the farm. Other future work includes finding a way to incorporate education about the aquaponics process with my project. A diagram, or a short video on an iPad would educate much more directly, where my project focuses mostly on aesthetics. Additional future work includes future maintenance of the system to ensure it continues pumping water to the plants, and that the plants stay healthy. Lastly, finishing the planters that are still left unconstructed would give the structure more planters, and would complete the dome/tree aesthetic that was developed in my original vision.

Conclusion

This project resulted in the construction of a living aquaponics art sculpture at the Student Experimental Farm. The project was a synthesis of different ideas and technologies working together for the promotion of PolyPonics and the Student Experimental Farm. The sculpture will continue to grow and develop over time; providing an attraction for the Zion aquaponics facility, an opportunity for people of all ages and backgrounds to engage with aquaponics, and hopefully inspiration for people to get more involved at the SEF.

Figure 31: The PolyPonics Team Left to Right: Myself, Dylan, and Eric

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Appendix A

Informed Consent Form
INFORMED CONSENT TO PARTICIPATE IN A RESEARCH PROJECT,
"Art with Aquaponics"

A research senior project on the use of art for the promotion of aquaponics technology is being conducted by Alex Horton, a student in the Department of Liberal Arts and Engineering Studies at Cal Poly, San Luis Obispo, under the supervision of Dr. Jane Lehr. The purpose of the study is to obtain data verifying the value of an aquaponics art piece on Cal Poly's campus as an installation that positively affects human levels of interest regarding aquaponics technology.

After visiting the Student Experimental Farm greenhouse, and seeing my aquaponics art installation, you are being asked to take part in this study by completing the following questionnaire. Your participation will take approximately 3-5 min. Please be aware that you are not required to participate in this research, you may omit any items you prefer not to answer, and you may discontinue your participation at any time without penalty.

There are no risks anticipated with your participation in this study. Your responses will be provided anonymously to protect your privacy. Potential benefits associated with the study include the evaluation of the aesthetics of this project, as well verifying the potential of art as a tool in the promotion of aquaponics technology.

If you have questions regarding this study or would like to be informed of the results when the study is completed, please feel free to contact Alex Horton at (408) 410 6604 or Jane Lehr at (805) 756 2511. If you have concerns regarding the manner in which the study is conducted, you may contact Dr. Steve Davis, Chair of the Cal Poly Human Subjects Committee, at (805) 756-2754, sdavis@calpoly.edu, or Dr. Dean Wendt, Dean of Research, at (805) 756-1508, dwendt@calpoly.edu.

If you agree to voluntarily participate in this research project as described, please indicate your agreement by completing and returning the following questionnaire. For your reference, please print a copy of this consent form before proceeding to the questionnaire, and thank you for your participation in this research.

Yes, I volunteer. No, I decline.

[buttons will open/close survey]

Survey:

Please provide a short response to the following prompt/question:

1) Describe what you knew about aquaponics prior to visiting the Student Experimental Farm.

2) Do you feel this installment has added or subtracted aesthetic value to this aquaponics facility? How?

Please indicate whether you agree or disagree with these statements (strongly disagree, disagree, neither agree nor disagree, agree, strongly agree)

a) Prior to attending this exhibit, I was interested in aquaponics.

(strongly disagree) (disagree) (neither agree nor disagree) (agree) (strongly agree)

b) After attending this exhibit, my level of interest regarding aquaponics has increased.

(strongly disagree) (disagree) (neither agree nor disagree) (agree) (strongly agree)

c) After attending this exhibit, I am more likely to involve myself with aquaponics in the future.

(strongly disagree) (disagree) (neither agree nor disagree) (agree) (strongly agree)

d) After attending this exhibit, I am more likely to involve myself with the Student Experimental Farm in the future.

(strongly disagree) (disagree) (neither agree nor disagree) (agree) (strongly agree)

e) After attending this exhibit, I am more likely to consider creating project of my own at the Student Experimental Farm.

(strongly disagree) (disagree) (neither agree nor disagree) (agree) (strongly agree)