Urban Farming

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Non-Traditional Community Supported Agriculture

PROJECT BACKGROUND

This project came about in the Spring of 2019. The initial project was focused on the mobile market that would deliver produce to specific consumers in the community facing a food desert. In low-income communities there are several barriers to fresh foods, these include ability, availability, childcare, cost, health, location, reliability, safety, time, and transportation. Our target audiences were single parents, the elderly, and no vehicle households. The crossover between these populations would be specific neighborhoods and apartments, bus routes, churches, or even WIC locations. This semester we decided to focus on existing networks within Gary, specifically the religious networks that exist. This decision was based on the skillset of the team and the feasibility of creating networks to deliver food through. We also decided to focus our efforts on establishing a CSA program (Community Supported Agriculture). This would allow us to tailor the packages to cultural preferences and health concerns in the area.

There are quite a few health concerns that the population of Gary, Indiana faces and a majority of them are related to diet. For example, as shown by the graphic, obesity, diabetes and heart conditions are some of the most common diseases that face the community.

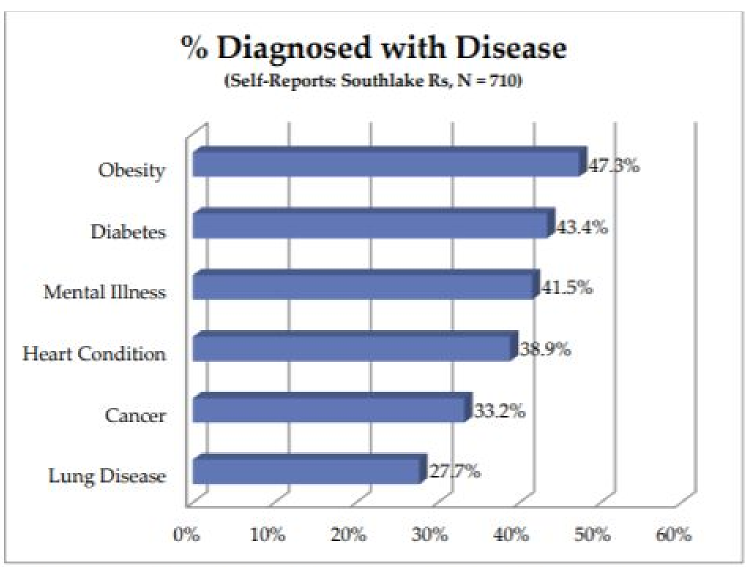


Figure 1. % Diagnosed with Disease" 2016. 2016 Survey of the Community. Methodist Hospitals, Southlake Campus. Pg. 21

When looking into the reasons for the rate of these diseases being so high, Southlake Hospital found that even though, those in Lake County, on average, had higher access to safe places to exercise than Indiana as a whole, on average, they had, on average, much lower access to fresh produce. This finding shows that exercise alone does not make up a healthy lifestyle alone, a healthy diet is also a significant portion of a healthy lifestyle. Some benefits of having a healthy lifestyle include having energy throughout the day, having a stronger immune system and having the ability to prevent diet-related illnesses, including some cancers.

Obesity, diabetes and heart conditions tend to stem from high cholesterol over long periods of time. In choosing which vegetables to grow and which recipes to share with the community, we did some research into foods that lower cholesterol and into types of diets that can lower the risk of being affected by one of these diseases. We found that some of the best ways to lower cholesterol are, eating foods that are low in saturated fat, trans fat, and sodium, eating lots of fruits and vegetables, eating fiber-rich whole grains, and fish and nuts and seeds, trying to eat some meals without meat, consuming lower-fat dairy products, limiting sugary drink intake and limiting consumption of red meat. We also found that a plant-based diet can lower one's risk of Type 2 Diabetes by 23%. We took all of this information into consideration when we decided which crops we are going to grow and when we were coming up with recipes.

PROJECT IDENTIFICATION

Community-supported agriculture (CSA) is a system that connects the producer and consumers within the food system more closely by allowing the consumer to subscribe to the harvest of a certain farm or group of farms.

Urban Farming's CSA program targets the individuals located within the "food deserts" in Gary, Indiana. More specifically, our team plans to use the pre-existing networks in Gary's community, such as users of food pantries, bus commuters, churches and other religious groups, and residents that interact with Peace Garden and Farms. Within these targeted groups, our CSA will also serve to benefit the members that are at risk or currently suffering from severe health issues regarding their current diets, like diabetes, obesity, or heart disease. Current organizations and group members in the Gary area from Purdue Extension, Lake County Eats Local, and the Northwest Indiana Philanthropic Foundation will be of great service at representing the goals of this project. These are individuals that are familiar with the community members, their daily lives, and typical diet culture. They can help distribute surveys at food banks and pantries to gauge what foods should be supplied by the CSA. The overall evaluation of the project will be determined by implementing more surveys to receive answers from the community regarding the usefulness of recipe cards and nutrient facts. Another method we will use to measure the success of the CSA will be to calculate and estimate the ratios of fresh foods in the diets of the members before and after the CSA. Typically, a CSA requires consumers to pay for the service upfront before the season starts, this is not feasible in Gary. We will apply for grants to fund the beginning of the season, just as the sum of all of the CSAs, and will create different packages based on the users family size and needs.

The CSA project has three main goals: 1) Improve the availability of and accessibility to fresh produce within Gary's community by incorporating produce from Peace Garden and Farms 2) Address current dietary concerns and related health disparities amongst the population of Gary 3) Promote food sovereignty by providing educational components for the community to better understand their rights to easily accessible, nutritious, and culturally appropriate food.

As Peace Garden and Farms increase production through its hoop gardens and aquaponic systems, our CSA team plans to distribute the produce through local organizations such as food pantries. We hope that Peace Garden and Farms produce may also be sold in local convenience stores and markets. As places to buy fresh produce become more accessible in Gary, we combat the food desert in the area one step at a time. By working together with local health centers and hospitals, we would like to use our produce to promote healthy eating in the area. We also plan to distribute healthy recipes with the produce that we sell to provide Gary residents with a variety of ways of cooking lesser-known vegetables.

EXPECTED SEMESTER TIMELINE

The team broke down the project in different phases to understand the tasks associated with each one. The phases do have some overlap in the time expected to complete them, but for the most part, should be done in chronological order.

PHASE ONE: Produce

Our goal in Phase One is to develop a plan for planting and harvesting the produce for the CSA. We will understand the availability of produce throughout the year. This data will be valuable in Phase 2 when we develop meal packages.

PHASE TWO: Packages

In Phase Two, we will develop the items that go into the packages besides the produce, this would include recipes, proper food storage tips, information about the health benefits, and other material from Peace Gardens and Farms. In this phase, we will also determine the dimensions of the container.

PHASE THREE: Procedures

This phase will be dedicated to developing procedures for safe food practices, harvesting, cleaning and sanitizing produce, storage, delivery, and establishing a currency for the CSA.

PHASE FOUR: Delivery

This phase is focused on the interactions between consumers and Peace Gardens and Farm. We will develop a web page to market the CSA and host information about the program. We will develop a network of community representatives and potentially work with existing food systems.

PHASE 5: Impact

We want to understand the impact of the program, we will explore educational opportunities as well as gather feedback from CSA users to adjust the program.

ONGOING PHASE: Grants

As mentioned, we are looking for grants to fund some of the farm operations. We have developed a list of typical questions from grants to prepare ourselves for each application. We will be applying for grants throughout the entire process.

SPECIFICATION DEVELOPMENT

Stakeholders Profiles

Evidence:

The primary stakeholder for this project is our project partner, Marty Henderson. He owns Peace Garden and Farms in Gary, Indiana. Our central communication about the project has been with Marty, and he is the one that ultimately makes decisions about the project and potential solutions the team presents.

Gary, as a community, is also a stakeholder since the goal of the garden is to provide healthy and fresh food that is easily accessible to them. In order to satisfy the community, the garden must have appealing and nutritional foods that are culturally relevant to Gary, must be sustainable and provide for several harvesting seasons, and the food must be distributed so that it is easily accessible for the community members. Marketing and communication about the garden must also reach the community. The population of Gary, IN is 35.9% in poverty, 13.7% of the population under 65 have a disability, and 4.7% of the population live in a household that speaks a language other than English. The effectiveness of the garden is partially dependent upon accessibility and community awareness of the food. Thus, transportation, having someone possibly deliver food, and advertisements in other languages may be aspects to consider.

In addition to the Gary community, stakeholders will include the individuals that will be working in the garden such as workers and volunteers. Although school-aged groups will also be working in the garden, they will identify as a separate stakeholder entity. The garden must be easily accessible for all ages and non-disabled individuals. Access to the roof must not be too physically straining, tools and garden supplies must be kept on the roof to make the maintenance efficient and straightforward, and the garden layout must accommodate space large enough to walk, pick weeds, harvest vegetables, and maintain the overall area.

As previously mentioned, the school groups that work with the garden are also stakeholders. They will be working on the garden maintenance during the summer months, and it is crucial that garden supplies and access to the roof are secure, accessible, and efficient. Additionally, the consideration of spatial layout and rooftop structural integrity must be able to accommodate large groups of people.

Finally, another stakeholder is the group of justice served individuals, such as Chris, who work with Marty on community re-entry. It is essential to be sensitive to their experiences and offer meaningful leadership and work opportunities for them that will provide skills and experience that can be used in the workforce and community. Production of the garden may go to convenience stores to be sold. It will be important to develop professional relationships with local grocery stores to do this.

<u>Contacting Community Partners:</u>

We contacted food pantries in the area to get advice on our CSA model. Unfortunately, we were unable to get into contact with anyone. We have reached out to our community partners (Purdue Extension and Marty Henderson) and they are attempting to get into better contact with the food pantries. We have created a stakeholder map to better see the available community partners in the area.

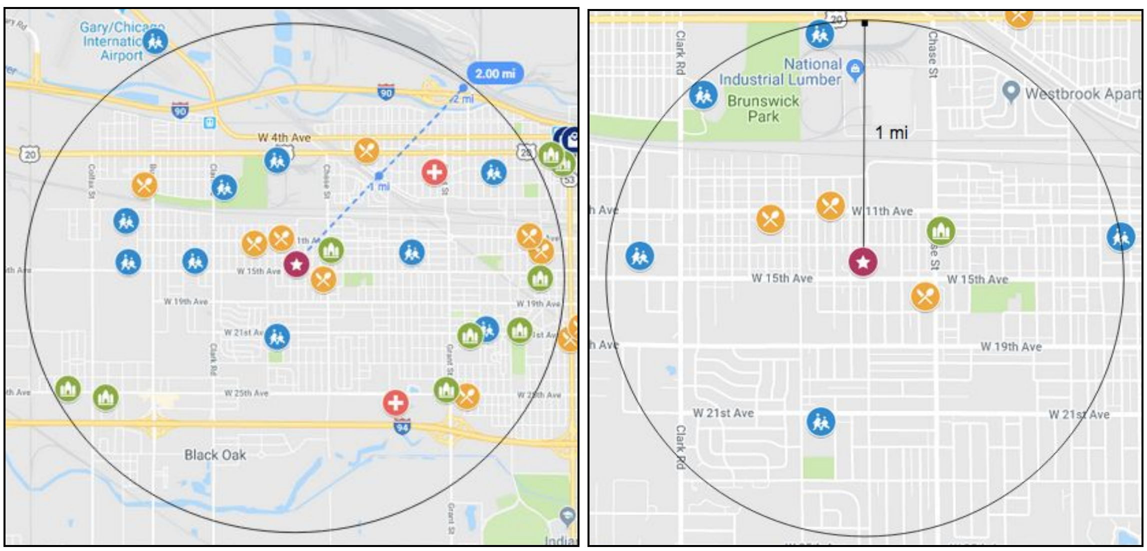


Figure: *2 mile and 1 mile analysis of community*

<u>Stakeholder Map Data:</u>

	1 mile	2 mile	Gary
Estimated Number of Families	86.95	344.53	1368
Food Pantries	3	8	18
Schools	4	9	43
Hospitals	0	2	5
Places of Worship	4	7	1057

Task Analysis

Evidence:

According to the Feeding America Study, Gary, IN currently possesses 14 of the 24 food deserts in Lake County (Reed, 2018). To address the lack of access to fresh produce and healthy food, Marty Henderson and Purdue University have partnered to build an agricultural system consisting of for the community. According to the U.S. Census Bureau, as of 2017, Gary has a population of 76,008, and 35.9% of the population is in poverty. The issue of combined poverty, lack of fresh produce, ability to use Supplemental Nutrition Assistance Program (SNAP) across more fresh food markets, and community empowerment and involvement are all factors in addressing the needs of Gary through a sustainable garden.

Our team of interdisciplinary college students aims to address Gary's lack of easily accessible and nutritious foods via implementation of a CSA program. This strong group of individuals proposes the CSA project has three main goals: **1)** Improve the availability of and accessibility to fresh produce within Gary's community by incorporating produce from *Peace Garden and Farms* **2)** Address current dietary concerns and related health disparities amongst the population of Gary **3)** Promote food sovereignty by providing educational components for the community to better understand their rights to easily accessible, nutritious, and culturally appropriate food.

Benchmark

Evidence:

Community-supported agriculture (**CSA model**) is a system that connects the producer and consumers within the food system more closely by allowing the consumer to subscribe to the harvest of a certain farm or group of farms. It is an alternative socio-economic model of agriculture and food distribution that allows the producer and consumer to share the risks of farming.[1] The model is a subcategory of civic agriculture that has an overarching goal of strengthening a sense of community through local markets.[2]

In return for subscribing to a harvest, subscribers receive either a weekly or bi-weekly box of produce or other farm goods. This includes in-season fruits and vegetables and can expand to dried goods, eggs, milk, meat, etc. Typically, farmers try to cultivate a relationship with subscribers by sending weekly letters of what is happening on the farm, inviting them for harvest, or holding an open-farm event. Some CSAs provide for contributions of labor in lieu of a portion of the subscription costs.

Project Partner Approval

Approval: Site Visit on 9/28/19

Specifications Document

Evidence:

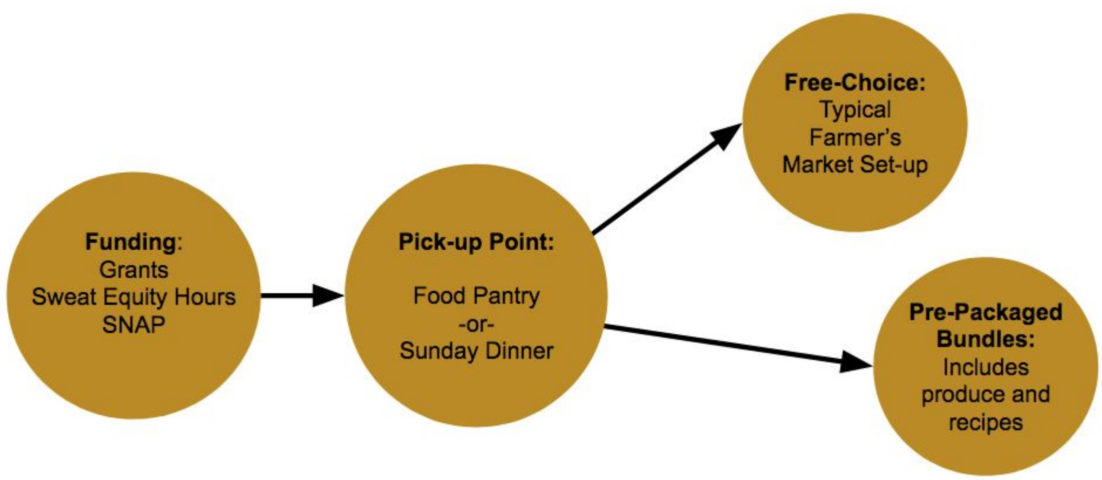
Urban Farming's CSA program targets the individuals located within the "food deserts" in Gary, Indiana. More specifically, our team plans to use the pre-existing networks in Gary's community, such as users of food pantries, bus commuters, and the members of Peace Garden and Farms. Within these targeted groups, our CSA will also serve to benefit the members that are at risk or currently suffering from severe health issues regarding their current diets, like diabetes, obesity, heart disease, and cancer. Current organizations and group members in the Gary area from Purdue Extension, Lake County Eats Local, and The Northwest Indiana philanthropic foundation will be of great service at representing the goals of this project. These are individuals that are familiar with the community members, their daily lives, and typical diet culture. They can help distribute surveys at food banks and pantries to gauge what foods should be supplied by the CSA. The overall evaluation of the project will be determined by implementing more surveys to receive answers from the community regarding the usefulness of recipe cards and nutrient facts. Another method we will use to measure the success of the CSA will be to calculate/estimate the ratios of fresh foods in the diets of the members before and after the CSA.

Summary of Specification Development

Using produce grown at Peace Gardens and Farms, we want to develop a CSA that addresses the different health risks that residents of Gary face. We are cross-referencing recipes, health assessments, and our potential produce to create the packages.

CONCEPTUAL DESIGN

Functional Decomposition



Procedures and Planning

Recipes:

Shift recipes to healthier food choices, this is done through choosing nutrient-dense foods within all food groups in places of less healthy choices. When developing healthy eating patterns, focus on variety, nutrients, and amount of foods.

> **Nutrient-Dense:** A characteristic of foods and beverages that provide vitamins, minerals, and other substances that contribute to adequate nutrient intakes or may have positive health effects, with little or no solid fats and added sugars, refined starches, and sodium. Ideally, these foods and beverages also are in forms that retain naturally occurring components, such as dietary fiber. All vegetables, fruits, whole grains, seafood, eggs, beans and peas, unsalted nuts and seeds, fat-free and low-fat dairy products, and lean meats and poultry—when prepared with little or no added solid fats, sugars, refined starches, and sodium—are nutrient-dense foods. These foods contribute to meeting food group recommendations within calorie and sodium limits. The term "nutrient-dense" indicates the nutrients and other beneficial substances in food have not been "diluted" by the addition of calories from added solid fats, sugars, or refined starches, or by the solid fats naturally present in the food.

Recipes were chosen based on nutritional value, availability of the ingredients on Peace Garden and Farms, preparation difficulty, and cultural importance. We used various websites and sources, such as Purdue FoodLink, USDA SNAP-Ed, and NHBLI (National Heart, Blood, and Lung Institute), to find our recipes. These sources focus on using healthy, modified recipes to promote healthy eating habits. Our project partner, Marty, emphasized the relevance of soul food in Gary, which helped us narrow down recipes from these large databases for our CSA Project. These recipes were compiled into a document in which the user can easily search for categories, such as breakfast or soul food, or ingredients, such as collard greens or peppers. This format is optimized for people in working Peace Garden and Farms who need to select recipes for packages or add recipes to the database. Below is a sample of the recipe document.

RECIPE	broccoli omelet
FOOD TAGS	breakfast, fast, high protein
INGREDIENTS	broccoli, sweet pepper
COOKING TIME	prep: 15, cook: 10
https://extension.purdue.edu/foodlink/recipe.php?recipe=Broccoli%20Omelet	

RECIPE	smothered greens
FOOD TAGS	soul food, side dish

INGREDIENTS	collard greens, kale, and onions
COOKING TIME	prep: 25 minutes, cook: 40 minutes
https://extension.purdue.edu/foodlink/recipe.php?recipe=Smothered%20Greens	

RECIPE	jamaican jerk chicken
FOOD TAGS	soul food, dinner, marinate overnight
INGREDIENTS	onion, hot pepper
COOKING TIME	prep: 6hr 20min, cook: 1hr 20min
https://extension.purdue.edu/foodlink/recipe.php?recipe=Jamaican%20Jerk%20Chicken	

RECIPE	vegetable stew
FOOD TAGS	soul food, heart-healthy,
INGREDIENTS	carrots, summer squash, hot pepper, onion, tomato
COOKING TIME	45 minutes
https://www.nhlbi.nih.gov/health/educational/healthdisp/pdf/recipes/Recipes-African-American.pdf	

Procedures:

For procedures, we first need to determine what type of food establishment we are. There are three main types: a food establishment, a retail food establishment, and a wholesale food establishment. A food establishment and retail food establishment are both regulated under 410 IAC 7-24, this procedure can be found on the Indiana Department of Health website. A wholesale food establishment is regulated under 401 IAC 7-21, this procedure can also be found on the Indiana Department of Health website. Some of the major points in both procedures that we will have to make sure we comply with is the procedure regarding potentially hazardous foods. Potentially hazardous foods are defined as produce that requires temperature control because of its capability to support the rapid growth of toxic microorganisms, among other things. We also have to consider worker training and health and hygiene, and the quality of the water we will be using to water and wash the produce with. There are exemptions to the procedures set forth in each situation that are based on the amount of income a food establishment makes, the procedures for these exemptions are typically on a case by case basis based on the resources that the food establishment has.

Phases Deliverables:

Phase 1: Excel sheet of harvest calendar

Phase 2: Create an example package
Includes recipe (according to the harvest season)
Produce that would be included (according to the harvest season)
What box/container we will use (and plan on how to acquire more at a cheap cost)

Phase 3: Create a harvesting procedure
Cleaning/sanitizing procedure
Storage procedure
Delivery procedure
Organic/safe food standards
Volunteering system + CSA currency

Phase 4: Create a website for CSA
Work with existing food systems
Compile a list of potential partners/stakeholders/food pantries/etc.

Phase 5: Create a feedback survey for CSA
Receive and analyze survey results

Phase Ongoing: Create a grant template
Apply for grants

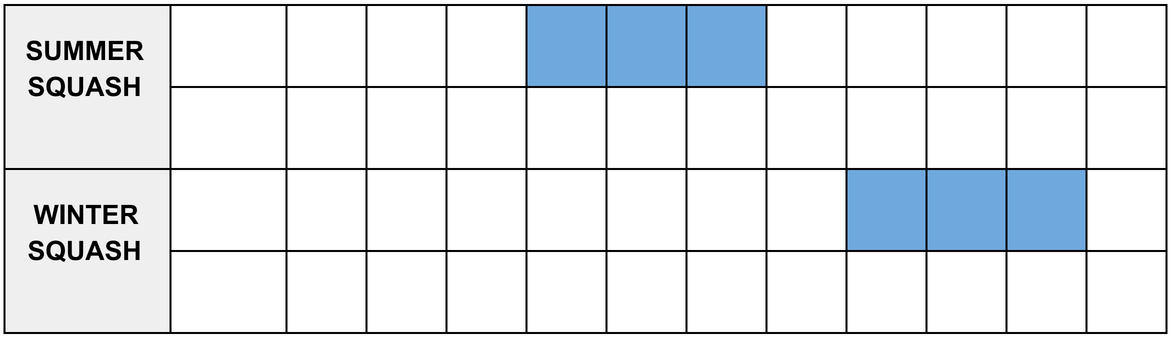
Summary of Conceptual Design

We are still developing the conceptual design for our project. We will be following the different phases that were outlined in the semester timeline section to gather data and apply our knowledge. A big piece of our conceptual design is the different procedures we have outlined. We need to have a complete understanding of how the food is harvested, sanitized, stored, prepared, and delivered to consumers.

HARVEST ANALYSIS

CROP	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
BEETS												
BROCCOLI												

CABBAGE												
CARROTS												
COLLARD GREENS												
CUCUMBE RS												
LETTUCE												
OKRA												
ONIONS												
HOT PEPPER												
SWEET PEPPER												
RADISHES												
SPINACH												



We received harvesting information from Marty through various tables and documents, detailing various elements of his harvesting procedure. Through Marty's records, we were able to obtain information on his transplant dates, the dates in which the plants grow to maturity, and harvest dates of his plants. The documents also entail the various types and seed varieties of produce Marty has on Peace Garden and Farms. The above Gantt chart displays data for the early and late harvesting seasons of his produce. Through this information, we will be able to time our deliveries based on harvesting seasons, determine which types of produce we will be putting in our food packages, and plan recipes we can send them with.

Vegetable	Harvest Season	Storage Time	Short Term Storage	Long Term Storage	Nutrition Facts
Basil	Year-round	3-10 days (wet) 3 years (dry)	Store in a bag with a wet paper towel at 50-65 degrees, if they have a stem, trim the stem and place upright in a glass of water and store in a cool place	Can be stored in freezer or dried	Low in calories
Beets	March-July	7-8 days	Store in a bag with a wet paper towel put in the fridge and use in 7-8 days	Frozen, pickled, dried, canned	Low in cholesterol, no fat
Broccoli	August-November	5-6 days	Store in a bag with a wet paper towel put in the fridge and use in 5-6 days	Can be frozen for 3-4 months	No cholesterol, low in fat, high in fiber
Cabbage	March-July	5-6 days or 2-3 days depending on storage technique	Remove outer, compacted leaves and store in the fridge in 5-6 days, place chopped raw cabbage in water and store for 2-3 days in the fridge	Can be stored in cold room, root cellar or in garbage bins, do not store long term inside or with other food items, the smell will permeate	Low in cholesterol, calories and fat

Carrots	April-July	2 weeks	Place ina plastic bag with damp paper towel and store for up to 2 weeks (baby carrots will not last as long)	Store in cool, damp room and pack with damp towels, use within a few months. Can be canned, pickled, dried, fermented or frozen	Low in cholesterol, fat, and calories
Collard Greens	March-August	5 days	Can be stored in a clean plastic bag in the fridge for 5 days	Uncooked and cooked collard greens can be frozen in plastic freezer bags for 4-6 months	Low in cholesterol, fat, and calories
Cucumbers	May-July	1 week	Can be placed in a plastic bag and stored in the fridge for up to a week	Can be canned and pickled	Low in cholesterol, fat and calories, mostly water
Chives	Year-round	7-10 days	Store fresh chives in the refrigerator in a resealable plastic bag, keeping the air inside, for up to a week. You can also place the stems standing up in a glass or jar filled with a few inches of water and covered with a plastic bag. Do not wash until ready to use the chives, as excessive moisture will promote decay.	Can be frozen. Use a resealable freezer bag, airtight container, or glass jar.	
Dill Weed	Year-round	2 days	Always store in the fridge either wrapped in a damp paper towel or with the stems in water (2 days)	Can be frozen and stored in a freezer-proof container or in ice cube trays covered in water (stored for up to 6 months)	Low in calories
Kale *(assume same as collard greens)*	March-August	5 days	Can be stored in plastic bags in the crisper drawer for up to 5 days	Can be frozen and dried	Low in cholesterol, fat, and calories
Lettuce	March-September	5 days	Wash and dry thoroughly, wrap in lint-free towel and place in a plastic bag, can be in the fridge for 5 days	Cannot be stored long term because of high moisture content	Low in cholesterol, fat, and calories
Mustard Greens	June-August	5 days	Gently wrap unwashed mustard greens in paper towels and store loosely in plastic bags. Keep moist and cool in the lower part of the refrigerator in the high-humidity bin.	Can be frozen. Drain off excess moisture, package in airtight containers or freezer bags and freeze immediately.	

Okra	May-July	3-4 days	Store in the warmest part of fridge in a loose perforated bag, use in 3-4 days	Can be canned, frozen or pickled	Low in cholesterol, fat, and calories
Onions	April-June	1-4 weeks	Depends on onion type	Store in a cool place can also be canned, pickled or dried	Low in cholesterol, fat and calories
Parsley	Year-round	5 days	Store in a plastic bag in the fridge for up to 5 days	Can be dried or frozen	Low in calories
Hot Pepper	May-July	5 days to 1+ week depending on method	Store on the countertop for 5 days or in fridge crisper for more than a week	Can be frozen or dried	Low in cholesterol, fat, and calories
Sweet Pepper	May-July	1 week	Refrigerate in a plastic bag and use within a week		Low in cholesterol, fat, and calories, high in vitamin C
Radishes	March-September		Cut greens off the top and store in a container in the fridge	Do not freeze well, can be pickled or fermented	Low in cholesterol, fat, and calories
Spinach	March-August	4-5 days	Store in a plastic bag with a damp paper towel for 4-5 days, you can also steam/microwave it and cool thoroughly with cool water and squeeze dry, this method takes up less space and makes meal prep easier.	Can be frozen for up to 5 months	Low in cholesterol, fat, and calories
Summer Squash	May-July	3-4 days	Can be stored in the fridge and used within 3-4 days	Can be frozen or dried	Low in cholesterol, fat and calories
Winter Squash	September-November	3-6 months	Can be stored at room temperature, unwashed for 3-6 months	Can be stored at 50-60 degrees for up to six months	Low in cholesterol, fat and calories

BRANDING

The inspiration for this logo comes from our mission and our demographic. Our mission is to create a community-supported agriculture system in Gary, IN in order to increase consumption and access to healthy and fresh produce. The “soul” represents the community we are helping—Peace Garden & Farms—and soul food.

We will use this design to brand our CSA. It will go on our packages and will be located at our pick-up points in either flyer or poster form.

Purdue Extension is assisting us in reaching out to local grocery stores to find available box sources for the packaging.

GRANTS

Grant Template

We have created a grant template to help us more easily apply to many grants. We have answered the following questions:

1. What is the project’s geographical scope?
2. What is the area’s demographic makeup and economic condition?
3. What challenges does your community face?
4. What actions has your community taken so far?
5. What is your proposed solution and what are the steps taken so far?
6. How do you propose to use the grant as a strategy to help address some of these challenges?
7. What other assistance related to this project has your organization and/or community received?

Project: CSA Goal: Increase Project Funding					
INPUTS	**ACTIVITIES**		**OUTCOMES**		
What we invest	**What we do**	**Who we reach**	**Why this project: short-term results**	**Why this project: intermediate results**	**Why this project: long-term results**
• Volunteers • Staff • Money • Crops • Fish • Materials • Equipment	• Provide fresh produce to those in food deserts • Provide those in food deserts with recipes on how to use fresh produce	• Low income population of Gary • Those without access to fresh produce	• Members of the community will have access to fresh produce • Members of the community will have knowledge of how to use fresh produce	• Community members will have a better understanding of how their diet effects their health	• Improved health of community • Lower rates of diseases such as cardiovascular disease, diabetes and obesity • Improved quality of life for the community

Assumptions	**External Factors**
• The community will participate in the CSA • There are people available to run the CSA	

The activities and goals of the CSA team combat food insecurity as well as implement healthy habits into the community. Our team has sought out a partnership with Franciscan Health, as it is a major healthcare provider in Lake County. By implementing healthy recipes, our team is focused on addressing health issues in the community such as diabetes, obesity, and cardiovascular disease. Left unchecked, these health concerns become issues that require hospital visits, therefore involving institutions like Franciscan. If our CSA program can act as preventative care, we can save money for hospitals and they can invest that money into our program.

SECTION 3: Prototype Considerations

Benchmarks and Progress: Design Considerations

Project Identification

The aquaponics project has three specific aims that fit into the project's overall goal:

1. **Improve the availability of fresh produce through indoor aquaponics in a USDA designated food desert.**
2. **Integrate a diversified farming system (aquaponics) into food desert-ridden Gary, IN to increase access to fresh and nutritious food products during both the winter and non-winter growing season**
3. **Provide a reproducible framework for further development of aquaponics systems in Midwestern food deserts.**

The team believes that our aquaponics system will provide fresh lettuces and fish during both the growing and non-growing seasons because it can be maintained in a controlled environment via artificial heating and lighting. In our aims, the creation of a curriculum and publication of research on how aquaponics can be pursued by individuals, schools, and other community groups. This is vital to amplifying the impact of the project beyond our project partner.

<u>**Experiment Location: ARMS 1098**</u>

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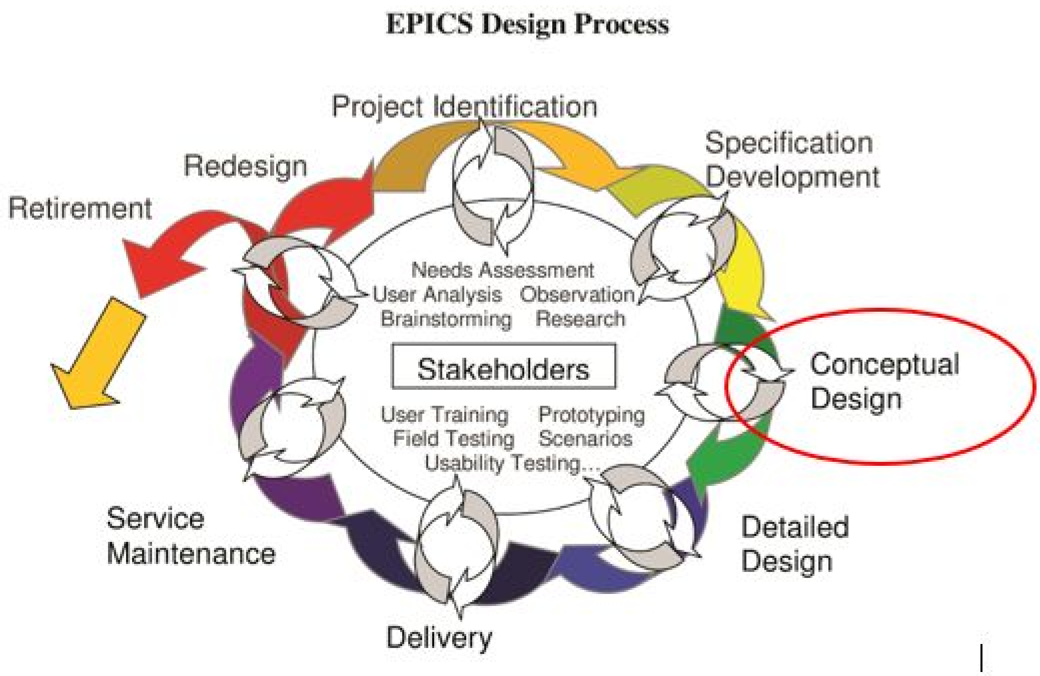


Figure: The EPICS Design Process cycle we are using for our project. At the moment, we are in the Conceptual Design phase.

The experiment is currently in the conceptual design phase. The goal of this semester is to gather quantitative data, operate the prototype, and gain lessons learned that will ultimately improve our final product to the project partner.

Measurable Benchmarks

To measure and quantify successful completion of the project, the team set design requirements based on the final design. Some of the considerations included:

- Exceeding the previous energy to vegetable output ratio established by the Arizona State study of conventional agricultural versus aquaponics.
- Successful publication of the project results in an open access format.
- Project approval from the Gary Food Council and Peace Farms to further upscale the aquaponics system.

Aquaponic systems have a long held reputation for being an energy intensive way of producing food at an accelerated rate. More specifically, in a hypothetical case study between conventional agriculture and aquaponics systems in Yuma, Arizona, aquaponics offered 11 ± 1.7 times higher yields but required 82 ± 11 times more energy compared to conventionally produced lettuce.

Ultimately, the final constraints that the design requirements address are set by the space of the building that the team plans to build the first aquaponics model in. The team also has design requirements of producing a certain amount of produce and fish to fully fit into the project partner's long term goal of feeding a specific number of families.

Customer Need	Customer Requirement	Measureable Value	Target Value	Current Performance
Size of System	Needs to fit within Motor Pool building footprint	sq. ft	1909.50	1909.50
Amount of Food (lettuce	Must be able to grow for 600 families	lb/year	3600.00	2040.00
Production Density	Must grow required amount of lettuce in footprint	lb/(sq. ft * year)	1.89	1.07
		heads/year	1.89	1.07
Cost of System	Needs to be economical	Break Even (years)	1.00	3.80

Figure: The design requirements set for the final aquaponics system.

To determine if the team's final plan satisfies the design requirements, the team implemented a prototype in the EPICS Labs as a proof of concept to verify the costs and energy of a final system, the potential production density, and the final size of the system The semester goals therefore revolved heavily around completion and operation of a prototype. To ensure the team had a logical plan in place, a semester timeline was created:

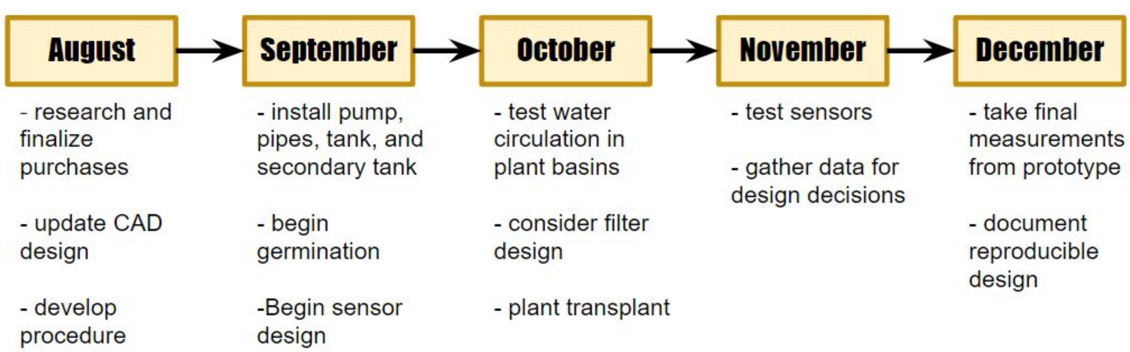


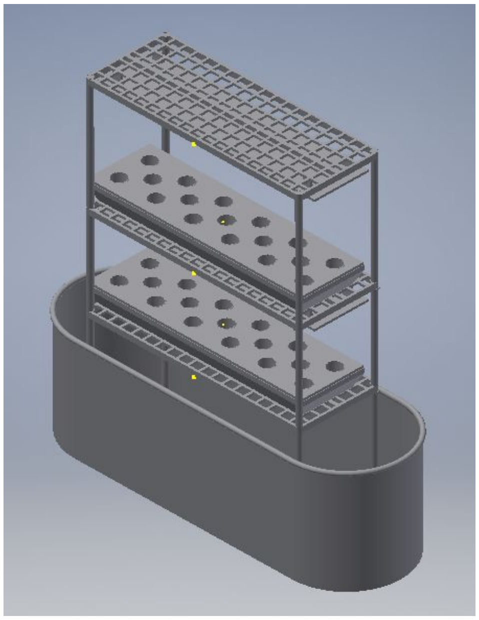
Figure: the prototype team's timeline for the semester

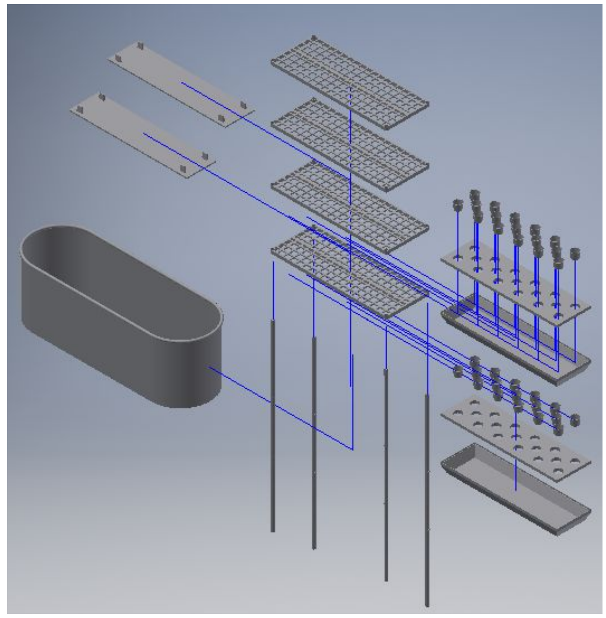
Updated CAD Designs

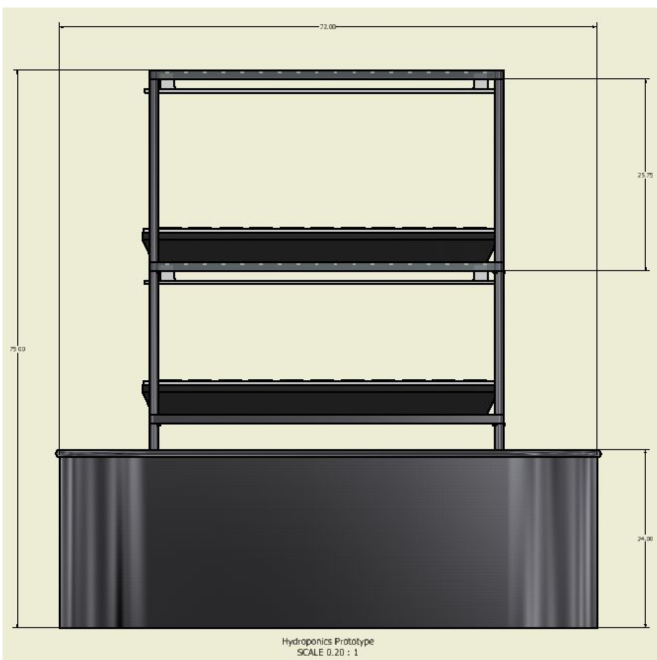
One of the crucial components to success was the successful updating of the model designs in CAD. Last semester the group designed and made the prototype and the parts of the prototype on CAD. The designs were very basic and did not provide a lot of detail. These designs are important in understanding how many plants we can plant and how much space each shelving unit occupies. These designs also can be used to visualize a final product and can be added to a CAD Design of a final product. The team can look at the designs and see how they want to layout the plants and shelving units. This includes using the actual dimensions of each part of the prototype.

Old Prototype Design

New Prototype Redesign







Early in the semester, the team created a Failure Mode and Effective Analysis table for the prototype. This aided the team in determining which key decisions would have to be made in certain additions that would need to be made to the prototype to have a successful outcome.

Failure Mode and Effective Analysis (FMEA) Table

Function	Potential Failure	Severity Rating (1-5)	Potential Causes of Failure	Occurrence Rating (1-5)	Process Controls	RPN (Risk Priority Number)
Operation	Spills	3	Tank Breaking, Structural Damage	1	Secondary containment and warning signs for non-group members	3
	Plant death/sub-optimal growth	1	Lack of nutrition, light, temperature	4	pH, nutrient, temperature monitoring and control, redesign of prototype	4
	Contamination of system and plants	2	Outside biological agents, dust, mold	2	Pump will be outfitted with water filter.	4
	Room Condition Variation	1	Room lighting, temperature	1	Factoring in effects of outside light and temperature into final prototype design	1
	Pump Failure	2	Clogging, poor manufacture	1	Back up pump in storage to install	2

Figure: Failure mode and Effective Analysis Table

Key Purchases and Decisions Made

For operation, a 20-gallon reservoir will be utilized as a holding tank to recirculate water to the plants. A system of flexible PEX tubing and a system of simple water pumps in the system will pump water to the trays. One of the possible risks included with this system is the risk for spills. A spill has the potential to have widespread effects that may affect electrical systems and laboratory space. In order to minimize the threat of this possibility, the entire prototype is housed in a large secondary container. The threat analysis to the prototype and the future aquaponics system is found above in the design document.

To avoid structural damage, signs will be placed on the prototype in all directions. The storage tank footprint is 6’x2’x2’ and created out of galvanized steel, therefore, the risk of bumps and outside contact is minimal.

For the prototype, the team needed to select the produce that would be grown in the prototype. In order to do so, a decision matrix was created.

Prototype Produce Decision Matrix

Criteria	**Weight**	**Pea Microgreens**	**Tomatoes**	**Lettuce**	**Peppers**
Cost of Seeds	1	3	2	1	2
Project Partner Input	3	2	3	5	3
Time to Germinate	2	5	3	4	2
Ease of Transplanting	4	3	3	2	1
Time to Harvest	4	5	3	3	2
Totals		51	41	44	27

Pea Microgreens (*Pisum sativum)*
Organic green pea seeds have a high germination rate and have been microbial tested for cleanliness. Pea shoots are the small beginnings of pea vines from seed to the 2nd leaf stage, where the lacy tendrils start to unfurl. Called micro greens, they are sweet and tender and may be consumed after harvest. Like other micro greens they are full of antioxidants, enzymes, and vitamins. The main factors for this produce being chosen to grow is the fast growth will allow for faster data on growth.

Iceberg Lettuce (*Lactuca sativa)*
More accurately called crisphead, this familiar pale green lettuce forms a tight, cabbage-like head. Its texture is crisp and its flavor very mild. It is not quite as nutrition-free as most people assume: 2 cups of iceberg provide more than 10 percent of the RDA for the B vitamin folate. The main factors of this produce being chosen is the input for the project partner.

Final Design System Plants and Fish

As stated above, we will only be using pea microgreens and iceberg lettuce in the prototype. However, when the final design is ready to be installed and set-up properly. The plants listed below are capable of surviving in the aquaponics system and will grow at a consistent rate. The following plants will be used in the aquaponics system:

Cabbage (*Brassica oleracea*)
Cannonball cabbage, more commonly known as green cabbage, is a dense leafy green vegetable used in multiple dishes. Harvest season is from March through July, but does not last long in storage. The smell is permeable in frozen storage units and suggested not to be stored this way. Canning is an excellent way to preserve this plant's leaves. Cabbage is low in cholesterol, calories and fat.

Collard Greens (*Brassica oleracea*)
Specifically chosen by Marty, one of our stakeholders, collard greens are a perfect choice to grow in an aquaponics system. These dark leafy greens are popular in most southern cooking recipes. With a long season, March to August, these greens can be harvested most of the year. Best way to store these greens is in a plastic bag, up to 4-6 months. They are high in iron and low in cholesterol, fat and calories.

Lettuce (*Lactuca sativa*)
Romaine Lettuce is one of the most popular lettuce species in the U.S. with sturdy ribs and is tolerant to high temperatures. March to September is the growing and harvesting months for romaine lettuce. Because of its high moisture levels, this lettuce cannot be stored for long periods of time, including freezing. Like all lettuces, romaine is low in cholesterol, fat and calories, considered one of the healthiest lettuces to consume.

Mustard Greens (*Brassica juncea*)
Mustard greens are closely related to kale, so it is long leafed plant with a distinct flavor of horseradish or mustard. This plant can only be harvested in the summer months. The leaves will be fresh for five days, but it will last a long time in frozen or dried conditions. This plant is low in cholesterol, fat and calories.

Spinach (*Spinacia oleracea*)
Spinach is one of the most commonly consumed leafy greens in the world. Spinach can be consumed throughout most of the year, but winter. Raw, canned, frozen and dehydrated spinach are all acceptable ways of consuming this plant. Low in cholesterol, fat and calories and high in calcium, fiber and vitamins A and C.

Basil (*Ocimum basilicum*)
Basil is one of the most common herbs to be used in food recipes with a strong, pleasant aroma. As the plant flowers, the taste will become tart and bitter, so flowers must be

trimmed to keep the sweet flavor. The plant will continue to grow leaves throughout its life if properly taken care off. Basil is best keep dried. The aroma of the leaves stays in the container, as long as it is tightly sealed.

Chives (*Allium schoenoprasum*)
Chives are a perennial plant, meaning that it will continue to grow until the plant exceeds its lifetime. The flavor of chives is quite bitter, but used in most recipes. Chives are excellent for aquaponics systems because the plant's roots will continue to grow stems, even Chives are best used when they are directly picked from the plant or can be kept for 7-10 days in a wet paper towel in a plastic bag.

Dill Weed (*Anethum graveolens*)
Dill is used with many dishes that include seafood, great for aquaponics. The plant is very absorbent of water, so it is best kept in a constant stream of cool water. The plant needs to be feathery and kept trimmed. Yellow discoloration in the plant is not healthy. Both the leaves (sweet) and seeds (citrusy and bitter) are edible. This plant be kept for only two days in the refrigerator or six months in a tightly sealed jar with water. Best used for canning or pickling.

Parsley (*Petroselinum crispum*)
Used in most hot dishes, parsley is great for cooking because of its strong flavor. When trimming the plant, look for strong, crisp leaves to harvest. The leaves can be kept for 5 days in the refrigerator or in a tightly sealed container in a dark, dry and cold storage unit.

Bluegill (*Lepomis macrochirus*)
Common length: 7.5 in
Lifespan: 5 years, mature after 1 year
Native to Northern America
Diet: Bluegill are opportunistic feeders and will feed on insects, insect larvae, small crustaceans, snails, plant material, and worms. 50% of their diet is midge larvae.

Lake (Yellow) Perch (*Perca flavescens*)
Common length: 7.5 in
Lifespan: 9-10 years, mature at 2 years
Native to Great Lakes, Mississippi River, and Northeast US
Diet: Yellow perch consume a wide variety of invertebrates, commercial fish food, insects, and small fish species.

Piping and Filtration:

When examining a final prototype design, the type of pipe utilized is important as different pipe types offer different costs and challenges. Ultimately, the team decided the pipes used to circulate water between the trays and the reservoir will be PEX, as they are flexible, freeze resistant and are able to withstand corrosion. PVC piping uses a specific glue that is poisonous to plants, PEX piping uses crimp fittings. A water filter will be placed to ensure there is no contamination or algae growth in the water. Cartridge filters will be placed in the water filter to consistently circulate clean water through the system. These cartridge filters will only remove types of biological molecules. The filter for the prototype allows for the intake and outake flow rates to be controlled by valves on the filters spouts. We will be controlling these flow rates to ensure that there is no overflow into the secondary tank, since this will only be used to catch water, not distribute it. T

Water Disposal Mechanism:

A system was needed for design in the event that water overflows into the secondary container or in any event where water needs to be disposed of from the trays. A secondary container was obtained and a hose system was installed to allow for easy access to dispose of into the drainage system. This decision was made immediately after the Failure Modes and Effective Analysis was completed.

Prototype Specifications:

The prototype built in past semesters consists of three shelves that are 24x48 inches. Each shelf consists of 17 cups for lettuce which have a radius of 1.35 inches and a height of 2.4 inches. The shelving unit is 72 inches high. The prototype also consists of two lights that are attached to the bottom of the shelf above it. To operate appropriately, the prototype will require 60 gallons of water to operate, creating a distribution of 20 gallons to each shelf and 20 gallons to a bottom reservoir that houses the pump system. The entire system will be contained in a galvanized steel secondary container to manage spills, which causes the entire footprint of the prototype to be 6’x2’x2’.

The lights in the prototype system are LED grow lights and are specifically designed to mimic the sun for the plants in order to aid their growth. It provides both light and a very minimal amount of heat to the plants. The effect of surrounding lights in the lab space will be neutralized through the use of a screen to prevent affecting the plant’s day and night cycle. This is as ambient light may still be active overnight, even if the lab is unused overnight. If plants are determined to be growing inconsistently, a shade system will be implemented to isolate outside lights if overnight darkness is inconsistent or an impossibility. The shade system will be a large fabric, plastic, or paper sheet oriented on the sides of the prototype that face the light.

After ensuring the prototype risks were minimized, the team also completed an analysis of the final design's risks and opportunities through a SWOT analysis.

Strengths	**Weaknesses**
● Large growing base ● Easy access to plants and fish ● Sustainable farming method for future generations to use ● System that can be easily duplicated to another system	● Higher chance for overflow problems ● Renovation of a garage to allow plants and fish to survive, comfortably
Opportunities	**Threats**
● Growing healthy, fresh food for a food desert ● Developing a new method for aquaponics ● Sustainable environment in Gary	● Plant and fish disease that is uncontrollable ● Failure to monitor system on a daily basis ● People refusing to eat the produce

Figure: SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis

Failure Modes and Effective Analysis of the Motorpool (FMEA)

Our FMEA of the motorpool considers almost all possible outcomes that will negatively affect the aquaponics system. Green ranked failures are not as concerning as the red ranked failures. The ranks are determined by multiplying the severity rating by the occurrence rate and detection rating. Severity is low and best if it barely affects the system and high if the entire system is affected. Occurrence rate is determined by how often it may happen to the system. Low values are good here. Detection rate is good is the value is low because we can easily detect where the problem is and what is happening. The top three concerns we have for the system are insect infestation, clogs in the drain and fish and plant diseases. Each concern affects a particular area of the system, but with each problem there is a solution to be used to counteract the concern.

Rank	Potential Failure	Severity Rating (1-10)	Potential Cause of Failure	Occurrence Rating (1-10)	Affected System Areas	Controls to Prevent Failure	Detection Rating (1-10)	Risk Priority Number (RPN)
23	Clog in the system	8	roots/leaves from plants entering the pump	6	filter, fish, pump, plants	adding a anti-clog drain	2	96
14	Power	8	storms	3	filter,	back-up	1	24

	outages				fish, pump, plants	generator		
4			downed utility lines	1	filter, fish, pump, plants	back-up generator	1	8
11			high power demands	2	filter, fish, pump, plants	back-up generator	1	16
19	Overflow from system	4	too much water being pumped throughout the system	4	plants, pump	access to proper drain system	2	32
8	Rain Load	6	consistent rain storms in the area	1	ceiling	adding a rain barrel/tank to the system to lower water bill and pH levels	2	12
9	Snow Load	7	snow piling up	2	ceiling	ensuring the roof can hold up to 25"/sq ft	1	14
17	HVAC system failure	2	clogged filter	3	people, plants	removing dust/contaminants from filter or replcing filter completely	5	30
11			blocked/leaky ducts	2	people, plants	clearing out the ducts or repairing them	4	16
1			outdated HVAC system	1	people, plants	replacing the HVAC system	2	4

						with a newer one		
3	Heat loss from interior of building	7	poor insulation of the building	1	people, plants, piping, fish, water	ensuring there is proper insulation in the motorpool for keeping heat in during the winter months	1	7
21	Fish disease	4	fish not being examined three times a week	6	fish, water, plants	monitoring fish behavior, scales, eyes, swimming patterns	3	72
20	Fish death	2	fish disease	6	fish	monitoring fish behavior, scales, eyes, swimming patterns	3	36
14			cannibalism	6	younger fish	separating young and old fish	2	24
13			fish becoming old	5	older fish	farming fish before they reach this age (5 years)	2	20
21	Plant disease	6	nematodes, fungi, bacteria, and mycoplasmas	4	plants, water	monitor plants living condition	3	72

17	Plant death	6	old plants	5	plants, production rates	care for plant until it can no longer produce leaves to harvest	1	30
5	Algea growth	3	stagnant water	3	water, roots	monitor water condition	1	9
24	Insect infestation	5	aphids	8	plant leaves	introduce ladybugs	6	240
5	WiFi outage	3	power outage	3	sensors	check power in the building	1	9
16			loss of signal	3	sensors	stronger router	3	27
1	Worker breaks	2	workers on breaks that cannot attend to the systems	2	people, plants, pumps, fish	workers who are not on vacation/ breaks can check in on system	1	4
10	Storm damages	5	roof damage	3	entire system	look at roof integrity, make improvements	1	15
5		9	structural integrity compromised	1	entire system	improve the walls in the motorpool	1	9

Figure: Failure Modes and Effective Analysis

SENSOR DESIGN AND DATA

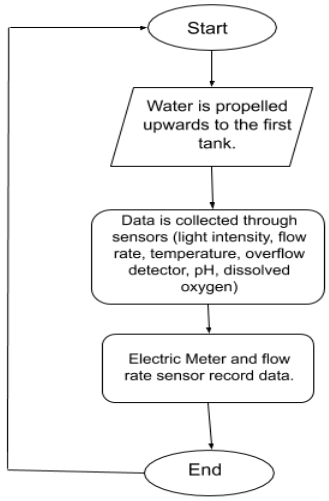


Figure: sensor design flow chart

Throughout the experiment, multiple forms of quantitative data will be obtained and recorded to allow for justification of design decisions. A waterproof electric meter, thermometer, pH strips will all be utilized by users for monitoring the system. However, there is a need for remote sensing of data as well. Therefore, sensors will be used to track data associated with running the prototype and make remote managing possible. Dissolved oxygen, temperature, light intensity, PH, flow rate, an overflow detector, and electric usage sensors will feed data to an Arduino mega that will send it to a Raspberry Pi 4 that will upload the data to a google sheet. The sensor placement is outlined below. There were two considerations in designing sensors. The first was the actual placement of the hardware, which is important in collecting data at specific points. The sensor placement may be viewed below:

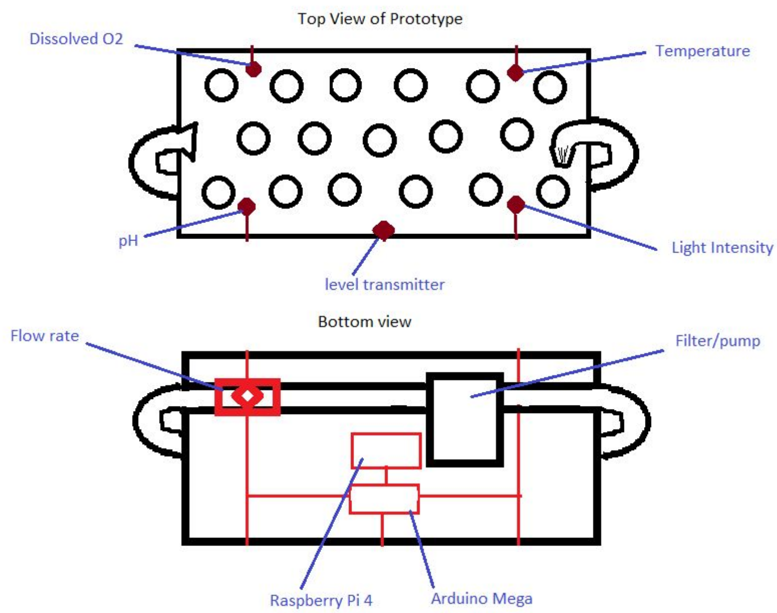


Figure: top and bottom view of our prototype

A second vital component is the software design. The collection of this data and software structure may be viewed in the following flowchart. This immediate flowchart is for the prototype. A flowchart for future design of the aquaponics system may also be viewed below.

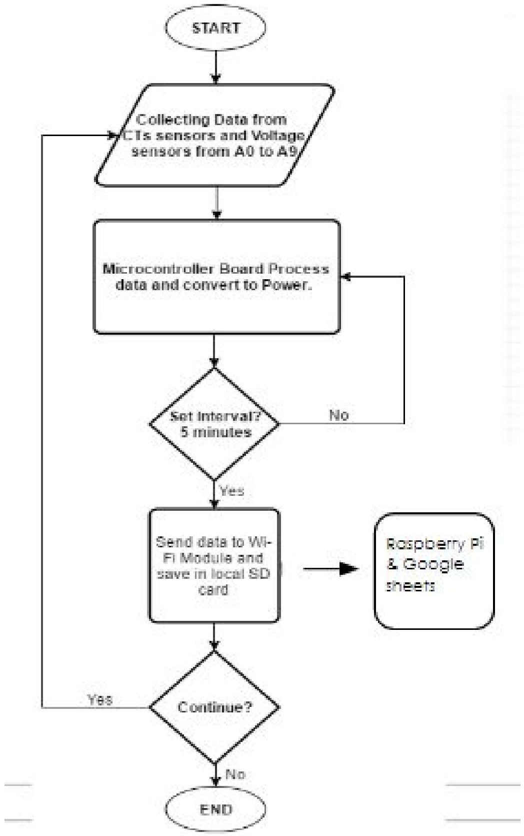


Figure: software design flow chart

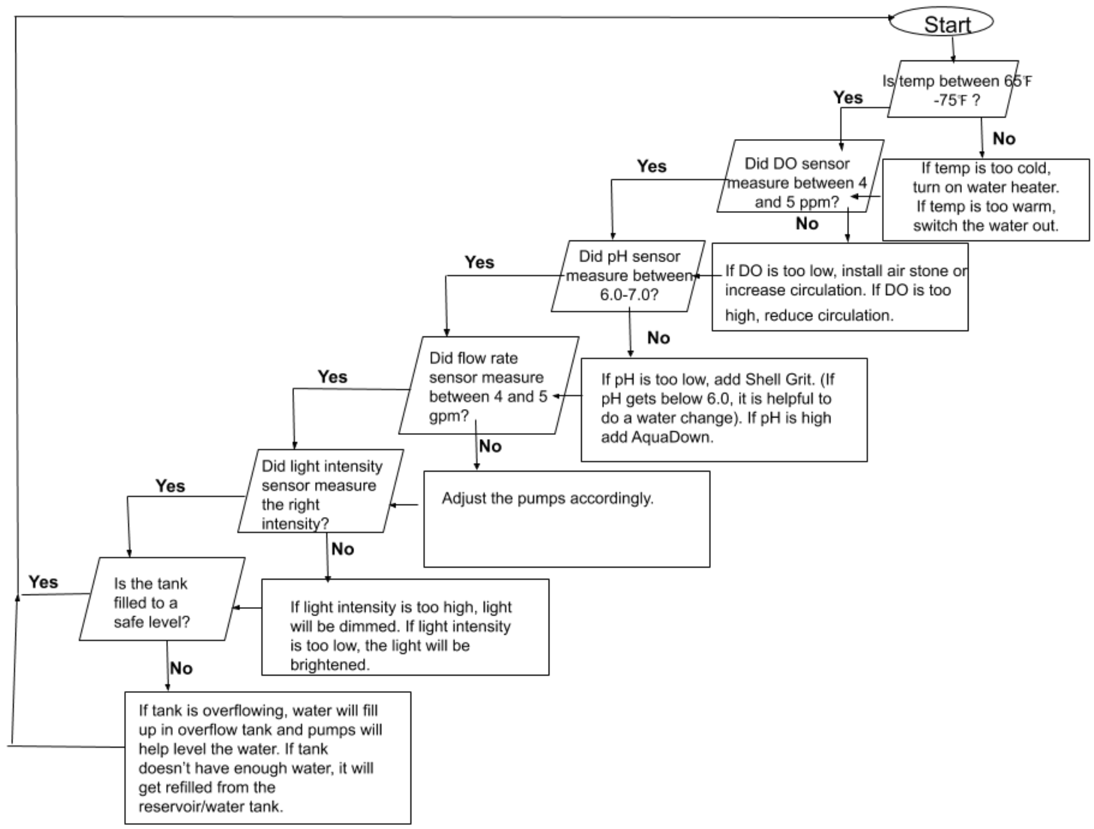
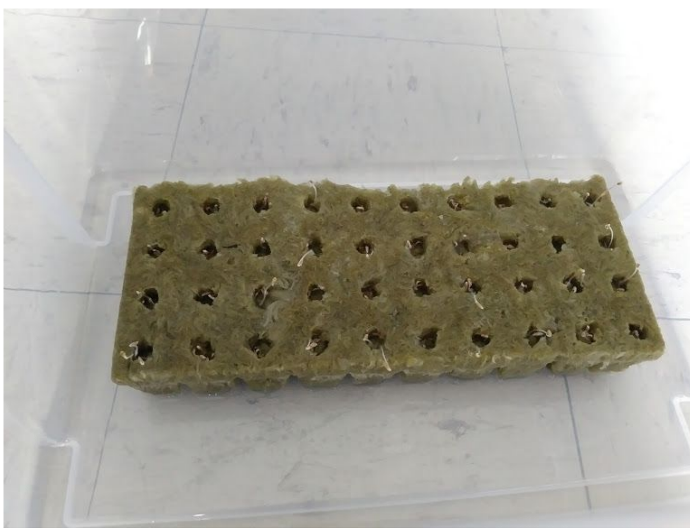


Figure: sensors flow chart

Growing Progress and Lessons Learned:

Figures: iceberg lettuce seed package and medium bought for germination

Figures: first batch of germinated lettuce seeds



Original Plan:

Our original plan was to grow iceberg lettuce seeds inside the cube pods, and have one of us take care of them until they were old enough to be transferred to the prototype. This group of iceberg lettuce seeds happened to have not survived as well as we wanted. The seeds grew up to be way too thin and long, perhaps from the inconsistent sunlight due to the changing of seasons. We began to start our prototype, and we decided to regerminate again, but this time with microgreens as well.

Regermination:

We pointed out our failures with the first batch of germinated seeds, and experimented with the new batch by placing them under controlled light, where the light was turned on and off to mimic real sunlight. The seeds immediately had a positive reaction to three weeks of consistent sunlight and water. We also realized that we transferred the seedlings into the prototype too quickly last time, and after researching, we decided that we will only transplant the seedlings once the width of their roots is an inch thick. Another major problem we encountered last time involved testing the water. We didn't test the water frequently enough, resulting in very basic pH levels and an unhealthy amount of ammonia in the water. During regermination, we tested the pH, ammonia, nitrite, nitrate, and phosphate. We also began recording and plotting our data to ensure that the levels are consistent.

Figure below: regerminated lettuce seeds

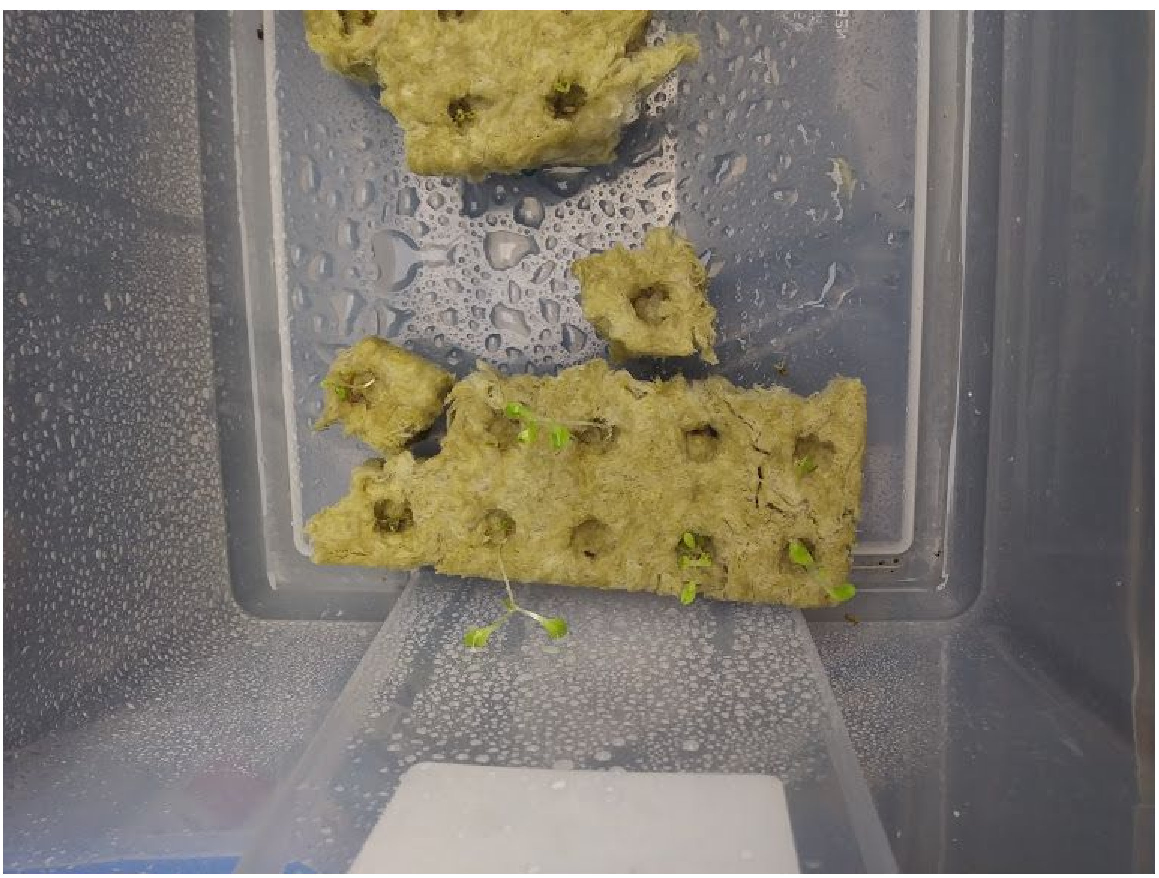


Figure below: germinated pea microgreens

Our lettuce seeds, although in smaller amounts and at a slower growth rate, are responding better than how the first batch reacted.

Our microgreens have been growing quickly and strong. The roots have been growing through the roots. We believe they might be almost ready to be transferred; if we do transfer them to the system, we will be checking the chemical and water levels like we have been doing for the last two or three weeks.

Our prototype was ready to start, yet we noticed that the water was off after we added fertilizer to the water. After the visit to the aquaponics garden in East Chicago, we decided to purchase a testing kit as well to help us measure the different chemicals in the water.

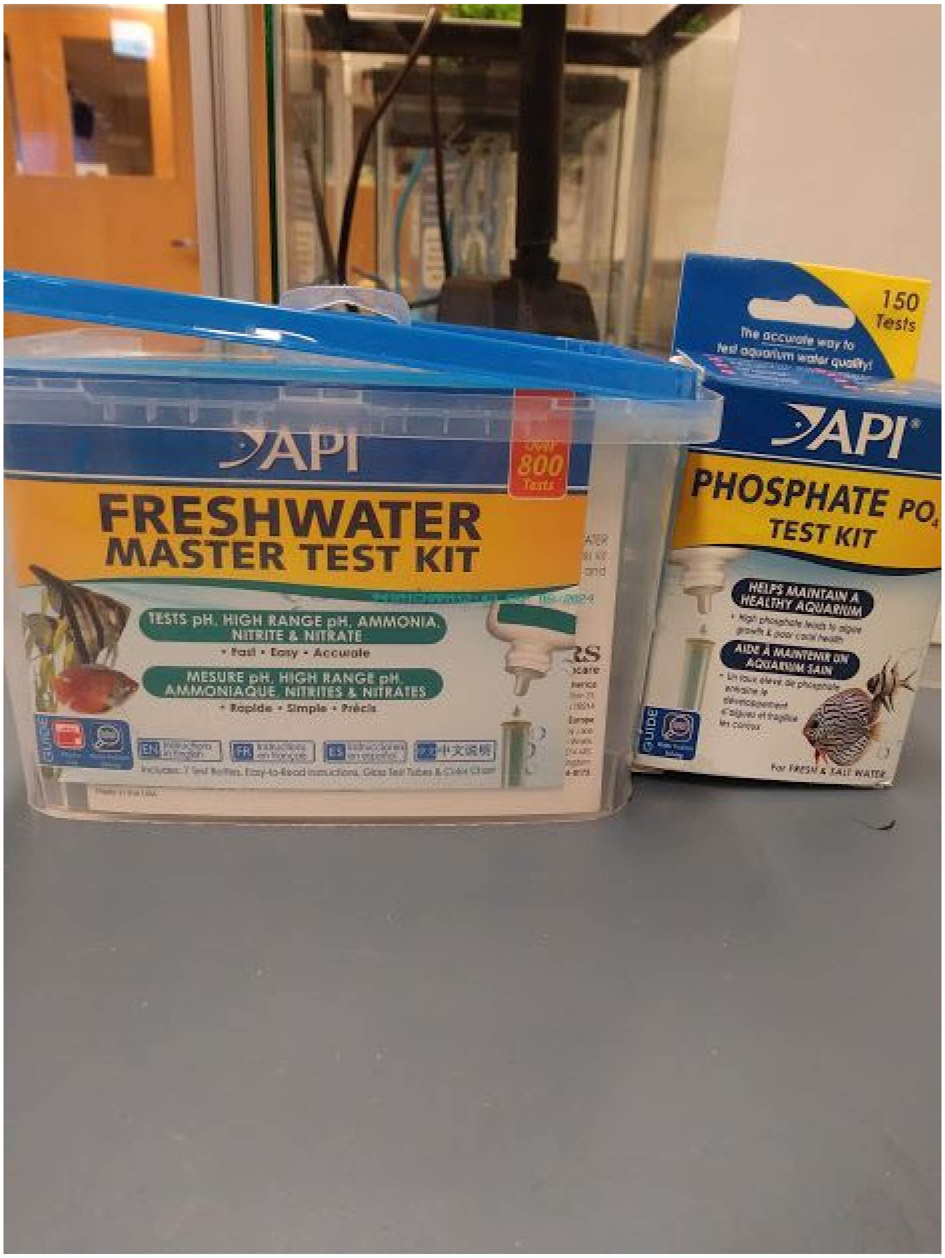


Figure above: testing kits we bought to test the water in our system

Testing for the past three weeks, we realized that there are some problems with the water, including high ammonia and PH. Before we can transfer any plants to the system, we will have to balance the chemicals in the water to sustain the plants. For now, while the seeds are still growing, we are testing the water and ensuring that when the plants are ready to be transferred, the water and the system will be running smoothly.

Based on input from professors that grew aquaponic and hydroponic gardens; we are following a method that worked for them. Feedback has been received from:

- Kathyrn Orvis, Assistant Professor of Horticulture
- Nathan Deppe, Greenhouse Facility Manager
- Krishna Nemali, Professor Controlled Environment Agriculture
- Sue Khalifa, Professional Civil Engineer
- Amanda Deering, Clinical Assistant Professor of Food Science
- Robert Rode, Aquaculture Research Lab Manager
- Paul Brown, Professor of Fisheries and Aquatic Sciences
- Tomas Höök, Professor of Fisheries and Aquatic Sciences/Director of Illinois-Indiana Sea Grant

Ideated Concepts:

- Grow the lettuce seeds with the fish for the prototype, but we were not allowed to experiment with live animals.
- Grow lettuce seeds in soil and then transfer to the prototype
- Grow lettuce seeds on a regular paper towel

Preliminary Water Data

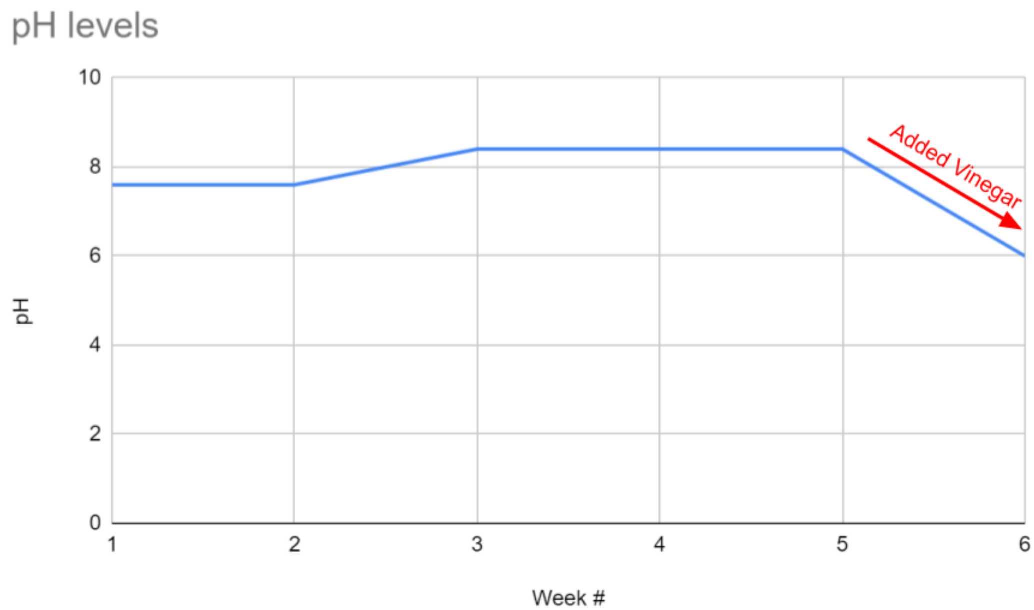


Figure: PH levels the water in our system had; there was a difference adding vinegar made to the levels

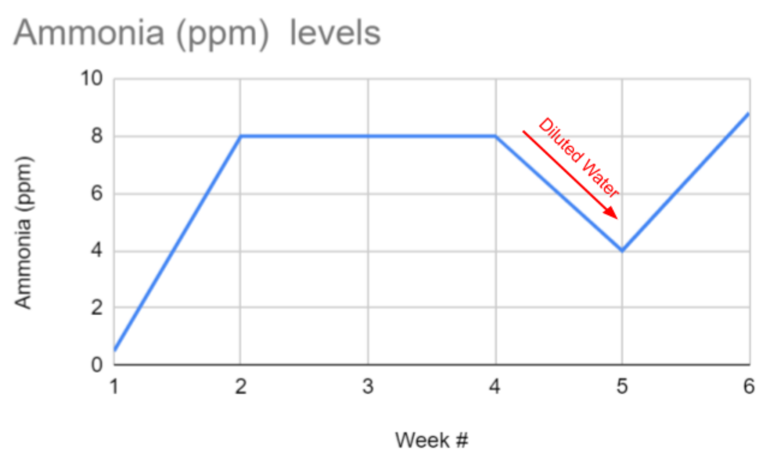


Figure: levels of ammonia in the water changed when we diluted water

Final Design Considerations

As discussed further in the Financials section, it has been determined that the ultimate goal of the project is to implement the project in phases, ultimately finishing at 40 prototype units to optimally have a high production density in the motor pool.

Operating Costs

The team has gathered valuable data from electricity meters this semester, which allows for extrapolation to the final design. The below spreadsheet shows cost per year of operating 40 prototype units in the motor pool layout. Cost per year calculated by multiplying by 365 days, then 10.53 cents/kWh. This calculation assumes 12 hours of operation for lights, 24 hours of operation for pumps. The average cost of electricity in Indiana is 10.53¢/kWh according to ElectricityLocal.com.

	kWh * 7 days	kWh/hr	hrs operating day	days	Total kWh/unit	Units	Cost
1 LED Light	6.45	0.038392857	10	365	140.1339286	80	$1,304.93
1 Pump	1.92	0.011428571	24	365	100.1142857	3	$34.96
						Total	**$1,339.89**

Figure: the cost of electricity for the system to function

Heating and cooling costs were also approximated, to give the prototype and financial teams a better understanding of the risks associated with operation of such a large system. Models were created from an Environmental Engineering Textbook and approximated using average monthly temperatures in Gary, IN (Mihelcic 2014). These calculations were heavily dependent on the size of the building and the R-value of the building, which is still being determined. The sensitivity analysis revealed that if the building is well insulated, roughly $730/yearly will be the heating/cooling costs. For medium insulation $1,170/year and for poor insulation $2,700/year.

Heating Estimation			Modeling Equation					Calculations f
Square F	2590		R wall	10		Wall 1	481	
			R ceiling	10		Wall 2	910	
Months	High	Low	Average	Days in Month	Difference from 65 F	Sides Heat Loss (Btu)	Ceiling Heat Loss (Btu)	
January	34	21	27.5	31	37.5	7761780	7226100	
February	38	24	31	28	34	6356313.6	5917632	
March	48	33	40.5	31	24.5	5071029.6	4721052	
April	60	42	51	30	14	2804256	2610720	
May	71	52	61.5	31	3.5	724432.8	674436	
June	80	62	71	30	6	1201824	1118880	
July	83	67	75	31	10	2069808	1926960	
August	81	65	73	31	8	1655846.4	1541568	
Septembe	76	58	67	30	2	400608	372960	
October	64	47	55.5	31	9.5	1966317.6	1830612	
Novembe	51	37	44	30	21	4206384	3916080	
Decembe	38	26	32	31	33	6830366.4	6358968	
					Total Btu	41048966.4	38215968	Yearly
					Total Kwh	12030.26322	11199.99	Yearly
		Sensitivity Analysis						
		Low	**$727.51**		**$ / kWh in Gary**	**0.1164**		
		Medium	**$1,171.57**		Cost per Each	1400.322639	1303.679	
		High	**$2,704.00**					
					Total Cost	**$2,704.00**		

Figure: heating and cooling costs for a year

Fish Tank Calculations

The tank will be used to store hundreds of fish. To determine the number of fish we will be raising in the tank, we were able to speak with Robert Rode, an aquaculture lab manager here at Purdue University. He stated that the fish will need 1-2 gallons for every pound of fish. Bluegill and lake perch can be harvested at one pound, about 1-2 years of growing. For every two plants in the system, about 2,040 plants in 120 trays at maximum, there will be one fish to supply nutrients. The following calculations were used to determine our tank size:

$$40\ stands\ * \frac{3\ trays}{1\ stand} * \frac{17\ plants}{1\ tray} = 2,040\ plants$$
$$2,040\ plants * \frac{1\ fish}{2\ plants} = 1,020\ fish$$
$$1,020\ fish * \frac{0.3\ lbs}{1\ lake\ perch} * \frac{2\ gal}{1\ lb\ of\ fish} = 612\ gal\ \text{(harvest grown fish)}$$

However, that is only for the fish. We would have to consider for all of the water in the trays and stands, in case the power went out and all of the water flowed back to tank. We determined that we will be using a 2,000 gallon tank to hold the fish and system's water. The 120 trays in the 40 stands will be holding, roughly, 1,200 gallons of water. This allows the fish to have more room in their tank, so they have less stress and live happier, healthier lives. The tank will be purchased from Poly Processing, a trusted open-top tank company. It will be five feet tall and eight feet in diameter. Only half of the tank will be full at a time, since most of the water will be in the trays, at any given time.

Reviewer Feedback

Reviewers wanted to ask feedback after every team's section. They felt that this would allow for more specific feedback. As a team, I would avoid this as for the prototype, it is fair to anticipate a lot of finance related questions on the aquaponics system that would be fully discussed later by finance.

Need to discuss stakeholder feedback we received at various points in the presentation. Asked why we did not choose traditional fish like tilapia for our final design. This is where we would have pre-answered this question by being more specific that our project partner wanted unique types of fish that he believed would be more suitable for his customers and consumers.

Need to address: How long for fish to fully grow. What is our turnover in fish?

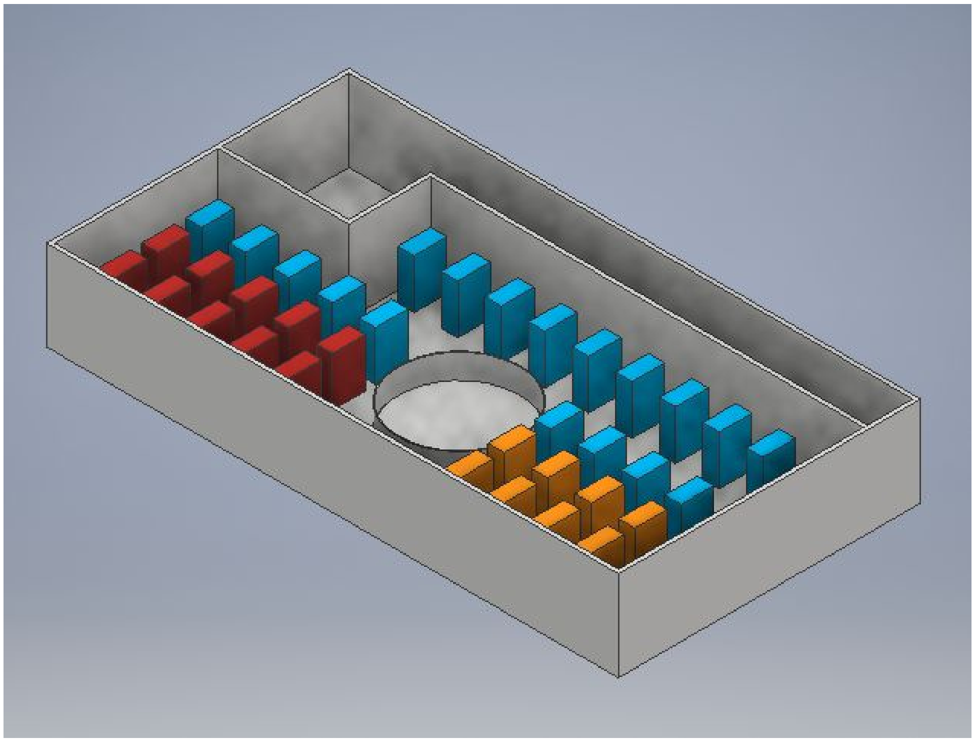
Wanted more background into the differences between hydroponics and aquaponics – this is the design lead's responsibility to understand the level of the audience. There is a critical balance in finding what is time appropriate and audience appropriate (do not want to be demeaning to the audience in explaining the most basic of terms) and I choose to do a brief overview of hydroponics and aquaponics. However, future DL could go into the background more.

Similarly, reviewers desired more background into the sensors. Perhaps for future presentations, we could discuss a brief background of automation in farming and why sensors are valuable to agriculture. Then remember to discuss what Raspberry Pis and arduinos are as well before introducing the sensor structure and how we collect data from the system.

Section 5 - Financials

This semester of fall 2019, we have completed a number of items. We have a comparison chart of the prototype cost vs. a pre-built design (see comparison section for detailed explanation), purchased all the prototype needs while ensuring we were within our budget, created a phase by phase budget sheet of the entire project, created charts for the return on investment, payback period, and net profit value estimates, obtained $1,200 from a Service-Learning Grant, and met with a discussed potential funding from the Franciscan Health Hospital group (see grants section for details).

We have created three phases to fund our project. Our first phase is retrofitting the building, finishing the lab prototype, and installing ten aquaponic units at our project site. Phase two includes installing ten more aquaponic system units at project site, creating an operation and maintenance manual, and calculating an accurate operational cost. Our final phase is installing 20 additional aquaponic units to the system, installing solar panels, and creating a long term ten-year detailed operational cost. Below is a diagram of our plan.



Phase #1	Building Retrofitting, Lab Prototype, 10 Aquaponic Unit Installation at Project Site, and One Year Operation Cost
Phase #2	10 Aquaponic Unit Installation at Project Site and One Year Operational Cost
Phase #3	20 Aquaponic Unit Installation at Project Site and Three Year Operational Cost

The lab prototype cost sheet is below with a total at the bottom of the list. This includes everything the Urban farming team has purchased since Spring 2018.

Material	**Quantity**	**Unit Price**	**Shipping**	**Total Price**
Ph sensor	1	164.00	0.00	$164.00
Dissolved Oxygen Sensor	1	290.79	0.00	$290.79
Electricity Usage Monitor	2	24.19	0.00	$48.38
Thermometer	4	9.99	0.00	$39.96
Flow Meter	2	12.99	0.00	$25.98
Printer Cable	1	5.10	0.00	$5.10
Light Sensor	2	5.39	0.00	$10.78
Raspberry Pi	1	55.00	0.00	$55.00
Raspberry Pi Charger	1	9.99	0.00	$9.99

Arduino	1	14.99	0.00	$14.99
Arduino Charger	1	8.99	0.00	$8.99
Breadboard	1	9.21	0.00	$9.21
Timer Outlet	1	13.99	0.00	$13.99
Dried Green Pea Seeds	1	8.39	0.00	$8.39
Clay Pebbles	1	23.42	0.00	$23.42
Lettuce Seeds	1	1.95	0.00	$1.95
Oasis Horticubes	1	16.24	0.00	$16.24
Miracle Gro	1	7.98	0.00	$7.98
Power Outlet Splitter	1	15.49	0.00	$15.49
Filter/Pump	2	34.29	0.00	$68.58
48” x 24” x 72” Shelving	1	319.00	0.00	$319.00
1’ x 4’ Flood Table	2	16.01	0.00	$32.02
1’ x 4’ LED lights	2	165.75	217.18	$548.68
Polystyrene Foam	1	15.02	0.00	$15.02
Net Pots	1	10.80	0.00	$10.80
Micro HDMI to HDMI Cable	1	$28.31	0	$28.31
32GB Memory Card	1	$9.36	0	$9.36
GFCI Protected 3 Outlet Splitter	1	$7.99	0	$7.99
Sensor push wireless thermometer	2	$49.99	0	$99.98
API freshwater Test Kit	1	$22.54	0	$22.54
8x10 Tarp	1	$7.99	0	$7.99
Hydronic Heating Pad	2	$11.99	0	$23.98
API Phosphate Test Kit	1	$12.50	0	$12.50
			Total Price	$1,977.38

In order to calculate an estimated cost of each phase and determine a breakeven point we have determined the approximate annual cost of running the system and estimated the total cost of retrofitting the motor pool building. We have reached out to several contracting companies to get an estimate cost for retrofitting the motor pool including Enspect, Falk PLI, and Burns and McDonell. We have yet to receive a response from them, so as a substitute estimate we approximated the cost of a new HVAC system and installing insulation in the building.

The total costs for the entire project is below. The chart is broken into the cost for installation, renovations, the prototype , and the operations. Those values were found for each phase. The total project cost is plus or minus fifteen percent of $79,478.

<table>
<tr><th></th><th>Phase 1</th><th>Phase 2</th><th>Phase 3</th><th>Totals With 3 Years of Operation</th><td rowspan="8">** Total Budget within 15% of Estimated Budget</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>**Installation**</td><td>$11,779</td><td>$9,597</td><td>$19,194</td><td>$40,569</td></tr>
<tr><td>**Renovations/ General Maintenance**</td><td>$18,803</td><td>$960</td><td>$1,919</td><td>$21,682</td></tr>
<tr><td>**Prototype**</td><td>$1,977</td><td>$0</td><td>$0</td><td>$1,977</td></tr>
<tr><td>**Operations (1 Year)**</td><td>$4,549</td><td>$4,949</td><td>$5,751</td><td>$15,249</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>**Total**</td><td>$37,108</td><td>$15,506</td><td>$26,864</td><td>$79,478</td></tr>
</table>

In determining a breakeven point, we used the assumption that all available growing space in the aquaponics system will be used to grow romaine lettuce (1,900 square feet), the variety with the highest sell price, and assumed that all the lettuce and fish will be sold at local store prices. This calculation takes into consideration the output of each different phase as they are implemented over three years. With these parameters the breakeven point has been determined to be after approximately four years. In addition to the breakeven point we calculated the Return on Investment (ROI) values for each year over a ten year period in order to look at the profitability of the system. This calculation also considers revenue based on selling all produce at store price and the results show continuous growth in the ROI values increasing from -0.7699 year one to 2.4308 year ten.

These charts show the net annual revenue after each installation phase. After all phases are installed, the Net Annual Revenue Phase 3 chart also represents the net annual revenue for every following year as long as the cost and sell price of lettuce and fish does not change.

Net Annual Revenue Phase 1				
	Iceberg	Collard Greens	Mustard Greens	Romaine
Blue Gill	$4,056.83	$1,822.77	$1,594.73	$6,174.02

Lake Perch	$3,943.79	$1,709.73	$1,481.70	$6,060.99

Net Annual Revenue Phase 2				
	Iceberg	**Collard Greens**	**Mustard Greens**	**Romaine**
Blue Gill	$8,415.55	$3,947.43	$3,491.36	$12,649.94
Lake Perch	$8,189.48	$3,721.36	$3,265.29	$12,423.87

Net Annual Revenue Phase 3				
	Iceberg	**Collard Greens**	**Mustard Greens**	**Romaine**
Blue Gill	$17,132.99	$8,196.74	$7,284.61	$25,601.77
Lake Perch	$16,680.85	$7,744.60	$6,832.47	$25,149.63

This chart shows the profit and return on investment after each year of running, with phases 1-3 being installed in the years 1-3. It distinguishes the summation of profit and profit per year and depicts a growing return as the years progress.

Year	Net Profit	Profit/year	ROI
1	-$20,654.41	-$20,654.41	-0.7699
2	-$21,305.43	-$651.02	-0.5309
3	-$20,758.93	$546.50	-0.3185
4	$4,842.84	$25,601.77	0.0743
5	$30,444.61	$25,601.77	0.4671
6	$56,046.38	$25,601.77	0.8598
7	$81,648.15	$25,601.77	1.2526
8	$107,249.92	$25,601.77	1.6453
9	$132,851.69	$25,601.77	2.0381
10	$158,453.46	$25,601.77	2.4308

Grants-

The entirety of the UF project startup will be funded by grants and sponsors. These grants will build up in order to fund each phase of the project and make funding more manageable. The CSA team has worked with the financial team to find, write, and create a grant template for grants this last semester. Refer to the CSA grant section above for grant and template information.

The financial team has worked on the following grants. Yearly, we apply for the Student Learning Grant through the EPICS program which supplies up to $1,500. This semester we obtained $1,200 from this grant. On top of this we are planning to apply to the Tomberg Philanthropies grant which can give up to $15,000. We have also reached out to Franciscian Health Hospitals to try and create a partnership with the organization. This partnership would supply us startup funding in exchange for helping with community health concerns surrounding a lack of available fresh produce.

Comparison-

The cost comparison model for the UF Fall 2019 team consists of assessing the current needs and objectives of the team in regard to goals that we have identified for the EPICS project this semester. We have taken the step of analyzing the current off the shelf solutions that can be purchased through numerous online retail stores. Additionally, we took the step of breaking the cost comparison model into two sections such as the team is generally broken into two sections. The first section being the Building: We need to understand or compare the cost that we have over time towards something that the Project Partner can understand. The second section is the Aquaponics system, in which we would like to allow for there to be something for the Project Partner to compare our system to.

Hence, the retrofitted building cost comparison model takes into account all the necessary equipment that would be required to drive a successful aquaponics system. The below table identifies the various potential sizes for a complete enclosed greenhouse building cost (this does not include the upkeep cost).

- These greenhouses include:
    - Frame and Hardware
    - Covering: Inflated poly on roof and both end walls
    - Evaporative Cooling system
    - Exhaust Fans
    - Power Vent Door Louvers
    - Air Inlet Shutter
    - Air Circulation System w/Jet Fan
    - Overhead Heater Package
    - Environmental Controls
    - Pre-wired Electrical Panel with Grow Light Controls
    - Exterior Shade Cloth
    - Assembly Manual
- These greenhouses exclude:
    - Lumber for baseboard and end wall framing (buying this locally saves you money)
    - Shading or insulation over the fish and filter tanks
    - Head house – not required, but can be built by customer
    - Generator

Farm Size	Cost
30' x 112'	$39,526
30' x 64'	$28,948
24' x 56'	$17,400
18' x 40'	$14,837
12' x 32'	$11,604
12' x 20'	$8,494

In regard to the Greenhouse Comparison Model, we analyzed all the equipment that is necessary along with the estimated yield. Therefore, we can truly assess how the size of the aquaponics operations performs (yields in fish and lettuce). The below graph provides estimates of the cost and yield, in which the prototype team can utilize this information to ensure that they are building something that will be beneficial to the Gary Community with a sizable cost savings.

Farm Size	Cost	Lettuce Production (lbs)	Fish Production (lbs)
30' x 112'	$59,995	32,250 - 46,350	1,900
30' x 96'	$49,995	34,944 - 52,416	867
30' x 96'	$45,409	12, 902 - 16,218	4,000
24' x 56'	$21,995	6,480 - 7,560	970
18' x 40'	$11,995	2,700 - 4,860	460
12' x 56'	$12,185	4,300 - 5,376	520
12' x 40'	$7,745	3,225 - 4,032	288
12' x 30'	$5,859	2,150 - 2,688	180
12' x 20'	$4,495	3,120 - 4,160	32
12' x 20'	$3,425	1,075 - 1,344	90

As a result, we have been able to create a rough estimate of our potential upside budget, in which we would obviously like to create a solution that is significantly below the max of the budget.

Current Aquaponics OTS Solutions					
Product Name	Rack Sqft	Grow Sqft	Sqft Comp	Cost	Rank
EPICS	480.00	120.00	4	$18,305	3

FarmTek	672.00	256.00	2.6	$12,185	1
Aquaponics	880.00	288.00	3	$19,995	2

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Farm Size	Actual Farm Size	Rack Sqft	Grow Sqft	# of Plant Sites	Sqft Comp	Cost	Calc Lettuce Production (heads of Lettuce)	Fish Production (lbs)
30' x 96'		2,880.00	770.00	#REF!	3.7	$45,409	0	880
24' x 48'	22' x 40'	880.00	288.00	216.00	3.1	$21,995	1,296	970
12' x 56'		672.00	256.00	378.00	2.6	$12,185	2,268	520
18' x 40'	11' x 35'	385.00	144.00	108.00	2.7	$11,995	648	460
12' x 40'		480.00	120.00	510.00	4.0	$17,853	3,060	255
12' x 40'		480.00	192.00	252.00	2.5	$7,745	1,512	288
12' x 32'	9' x 23'	207.00	72.00	54.00	2.9	$7,995	324	215
12' x 30'		360.00	128.00	168.00	2.8	$5,859	1,008	180
12' x 20'	6' x 16'	96.00	48.00	36.00	2.0	$4,495	216	110
12' x 20'		240.00	64.00	84.00	3.8	$3,425	504	90

The above table holds various off the shelf solutions, in which we gathered the overall square footage of the aquaponics system, the available growing square footage, a comparison of the square footage of the aquaponics system to the available growing space it offers, along with the cost and yield.

<u>Legend:</u>

- The highlighted section in blue is the EPICS solution
- The SQFT Comp is ranked: The greater the green color means that the ratio of the aquaponics system sqft to available growing sqft is the best. The more transparent the

green color means that the ratio of the aquaponics system sqft to available growing sqft is the worst.

- The Calc Lettuce Production is ranked: the greater the green color serves as the best most amount of lettuce production.
- The Fish Production is ranked: the greater the green color serves as the best most amount of Fish production.

Hence, to understand where our solution stands in comparison to other off the shelf solution we can break it down into four main categories: Sqft ratio, Cost, Lettuce Yield, and Fish Yield.

- The sqft ratio of our phase 1 aquaponics solution consumes consumes 480 sqft in exchange for 120 available growing sqft.
- The estimated cost is $17,853 for the aquaponics system alone.
- The Lettuce production yields 1,105 heads of lettuce a year, which is the 3rd best option in comparison to other similar priced aquaponic systems.
- The Fish production yields 173 lbs of fish per year, which is the 3rd best option in comparison to other similar priced aquaponic systems. However, more significantly it is the third lowest production yield in comparison to all the aquaponics systems. Thereby meaning that there are three other options that have greater fish yields with for a less expensive option.

In turn, the EPICS solution unfortunately does not compete with the current off the shelf solutions.

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