Combating Food Insecurity Through Greenhouse Optimization and Education

An Interactive Qualifying Project Report submitted to the faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements of the Degree of Bachelor of Science

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Executive Summary

Between 25% to 50% of college students are affected by food insecurity in the United States. The causes of food insecurity for college students include access to food, availability of food, awareness of the problem, and education. Food insecurity for college students has been found to contribute to lower education outcomes, lower lifetime income, and lower human health and personal development. Lower lifetime income can lead to living below the poverty line, which is $12,490 and $21,330 (over average) respectively (U.S. Department of Health & Human Services, 2019). Greenhouses have been used for centuries to optimize plant growth and to overcome significant environmental constraints. Presently, greenhouses utilize automated systems such as heating, cooling, lighting, and watering to improve the efficiency and yield in a variety of climates. When greenhouses are used to grow food and educate students, a greenhouse becomes a promising tool that can be used to address some parts of the food insecurity problem for college students.

Food insecurity of college students has been recognized as a problem across the country. To address this, colleges in the local area have recently started to create programming. One such school is Quinsigamond Community College. The honor society at the school, Phi Theta Kappa (PTK), started a greenhouse for that exact reason, which impacts 50% of the students. PTK has been running the greenhouse to address the problem of food insecurity since 2017, and has subsequently created a food pantry as well.

The goal of this project was to identify what components are necessary to make an optimized greenhouse that addresses the issue of food insecurity among college students. From the literature, we determine that a greenhouse program focused on achieving those aims must consist of three components:

- **Facility Optimizations**: This includes the actual facility structure, materials and equipment used in the facility, automation of systems, plants grown, organizational methods, sustainability practices, records, and safety measures.
- **Education & Outreach Programs:** This includes protocols for training staff and volunteers, experiments done at the facility, and community awareness of the facility/program.
- **Food Availability Programs**: This includes addressing food insecurity through programs, making food available, and assisting students apply for food and housing assistance.

To determine what aspects of these themes are the most important for optimizing a greenhouse, four case studies were conducted on college campuses with facilities that had at least two of the three components present; a greenhouse, an education plan related to the facility, and had some program for students that dealt with making food more available. Three greenhouses and one garden were selected based on the criteria, and using a Most-Similar method of case studies three forms of data was collected to ensure triangulation of data was achieved (Creswell, Clark, 2018, pg. 116).

Three sources of data were determined to be the best to conduct the case studies; background documents provided by the colleges, anonymous interviews of key stakeholders at

the facilities, and observational data of the facilities. This data was acquired after requesting an interview along with requesting access to documents, then conducting the interview and taking digital photos of the facility and environment. Once the data were collected, they were analyzed following an investigator triangulation method. Multiple people reviewed and interpreted both the interview answers and observational data, then organized all the findings and cross analyzed them across all four cases.

The findings determined the two most similar cases were the facilities that focused on research and experimentation, and the other two cases focused on food insecurity and horticulture training-type education. Due to the focus of these two groups, each have different goals for the plants that are grown, but many of the same practices were observed. This includes training staff to properly tend to the plants, utilizing the facility to include some sort of outside community involvement, using and storing some similar equipment, and offering some form of education for people of all ages.

There are multiple recommendations made to optimize a greenhouse to address food insecurity on a college campus. Based on our findings we recommend following the information in the table below. These are the key recommendations, and not an all inclusive list.

Table 1: Rankings of Key Recommendations for Creating an Optimized Greenhouse, for Addressing Food Insecurity on A College Campus

Rank	Key Recommendations
1	Create a food pantry program to stock food from the greenhouse.
2	The facility should be a large, modifiable, organized structure, with adequate sunlight that is safe and secure.
3	Create a training program to guide staff on how to maintain the facility and plants.
4	Use composting to grow plants that are nutritional, not difficult to grow, and won't be wasted.
5	Have automated watering, heating, cooling, and lighting systems.
6	Create a student greenhouse club on campus.
7	Connect with the non-college community by getting involved with REC's YouthGROW program.
8	Start a Food Security Task Force.
9	Incorporate national food assistance programs like SNAP and WIC.
10	Get involved in Voices of Hunger Summit.

The area that the greenhouse occupies should be larger than the greenhouse structure itself to allow for storage, community activities, and upgrades that belong outside the structure including renewable resources. The structure should be large, modifiable in part to allow for upgrades as well, such as the use of solar or wind power, or collecting rainwater.

Having a food pantry in tandem with a greenhouse is a key recommendation to fighting food insecurity. This allows for greater community involvement and outreach, but also comes with more work. Following only the recommendations listed above will make for a very adequate greenhouse program for addressing food insecurity. Although, to more nearly reach

optimization following the additional recommendations should be included in the program, as they will make it far more efficient.

Another key point is that a greenhouse is not the most optimal facility to truly optimize food output. To do this a freight farm is required, as it utilizes all automated systems, has available space with vertical growing, and has a much better control of the conditions inside the facility. This would also require a food pantry to adequately address food insecurity, but it comes with limitations, such as the ability to include outside communities for awareness. As space is designed to be utilized to the fullest extent, it also limits the education components that be involved in the program.

To truly work to combat food insecurity, education is a large factor, as such an education component should be integrated into the greenhouse program as much as possible. This is because it will work to create long lasting effects to position participants to have a greater understanding of what food is necessary for health, where some of their food comes from, and the importance of the entire process. This component of an optimization project should take precedence over some forms of optimization of the facility, such as automated watering for example.

1. Chapter 1: Introduction

1.1. The Problem Statement

This project goal was focused on the problem of food insecurity on college campuses. To address this problem we planned to help a specific college, Quinsigamond Community College (QCC) in Worcester, MA, by optimizing a greenhouse and improving their education program. This was achieved by conducting four case studies at four different colleges that meet two or three criteria. The criteria focus on the facility, the types of education and outreach available at the facility, and food availability programs. The data collected from the case studies includes interviews with key stakeholders of the facility, observational data from the facility, and logistical records (when available).

It has been determined that 25% to 50% of college students are considered food insecure. This problem not only impacts the students but the college and community as well, creating a cycle of problems that can only be fixed by combating food insecurity. While this problem is not limited to a specific demographic, this project focuses on college students because colleges already offer education programs, and students make up a large portion of our communities that will be making decisions and addressing all levels of problems across the world. As such, this population is a vital group of people to assist, especially as food insecurity of students does not garner the attention it needs.

1.2. Motivation for Project

Food insecurity hasn't had much serious attention given to it, which has resulted in minimal research efforts to address the problem. This is especially true for college students. In fact, community college students not only seem to be at greater risk for food insecurity but those who are impacted by it are more likely to fall into a lower GPA category (2.0 to 2.49) rather than the highest category (3.5 to 4.0) (Maroto, Snelling, Linck, 2014, pg.9 and 10).

According to the facility manager of Case 4, "The image of [college] students is about 'partying'; it's not about academics or students giving up basic needs for education."
The reality is there are more college students sacrificing basic needs to compete and succeed in academics than there are partying. Skipping meals is a common occurrence for many students, yet this behavior has only recently been given serious consideration and attention. While the cause of the problem may stem from the cost of education and living, or a systemic societal problem, these causes require a far greater deal of investigation to address. A much simpler area, which deals directly with the problem is growing food, and there is even less research focused specifically on growing food for food insecure college students.

1.3. Specific Goal, Objectives, Justificiations, and Implications

The goal of this project was to create recommendations for a greenhouse on a college campus which would include educational components and address food insecurity for students. This is done by researching facilities that already have some or all of those components, analyze

the data, and make determinations as to what will allow for an optimized greenhouse to address food insecurity. This is an important endeavour as college educated people are an asset to colleges, communities, and the planet. Food insecurity hinders education for a multitude of reasons, which is explored in the following chapter, but can be reduced through growing healthy food and educating people to grow such food.

In Chapter 2 we outline the background of what food insecurity is and how it impacts individuals and communities. There is also background information about greenhouses and how they work, daily nutritional requirements for individuals, and the current greenhouse program at QCC. Chapter 3 details the findings for each individual case, learned through multiple sources of data. Additionally a cross case analysis has been done, which compares each case to determine the best practices for optimizing a greenhouse program. Chapter 4 discusses our understanding of the findings, giving insight based on our background knowledge, and gives our recommendations for optimizing a greenhouse. Chapter 5 finishes the report with our final conclusions.

2. Chapter 2: Background

2.1. Introduction

This chapter presents the complex issue of food insecurity, specifically on college campuses, and how greenhouse programs can be used to alleviate this problem. To understand the nature of food insecurity we explore and elaborate on its current form, as well as its origin. Additional problems that are associated with food insecurity will also be detailed, such as the impact that food insecurity has on education, income, human development, and poverty. Historically, greenhouses have been used to address the issue of food insecurity, and recently some colleges have started building greenhouses on their campus as a solution for food insecure students. This chapter will detail food insecurity and some of its impacts, the functionality of greenhouses, how greenhouses work in regards to the greenhouse effect, and how a college greenhouse can be optimized through materials, setup, and the use of an education plan.

2.2. Food Insecurity

Food insecurity is defined as an ”indication of disrupted eating patterns, and some reduced food intake (“United States Department of Agriculture”, 2018). Presently food insecurity impacts over 11% (FAO, IFAD, UNICEF, WFP, WHO, 2018, pg. 2) of the 7.6 billion people on the planet (“U.S. and World Population Clock”, n.d.). 40 million people in the United States are food insecure (Feeding America, 2018). Massachusetts has a population of 6.5 million people

("Population Demographics for Massachusetts", 2019), with 10.3% of the households are facing with this issue (United Health Foundation, 2018), which is over 673,000 people (United States Census Bureau, 2018). It is projected that between 25 to 50 percent of college students are affected, which is upwards of 93,000 students (Broton, Goldrick-Rab, 2018, pg. 6; Broton, Goldrick-Rab, 2016, pg.4; Association of American Colleges & Universities, 2017; Jimenez, 2019). In the entirety of the United States there was a projected 19.9 million college students in 2018 (NCES, 2018), which means there are between 4.9 million and 9.95 million food insecure students.

2.2.1. Causes of Food Insecurity

Food insecurity has a complicated nature and impact (FAO, IFAD, UNICEF, WFP,WHO, 2018), these can range from a lack of or limited resources (Coleman-Jensen, Rabbitt, Gregory, Singh, 2018, pg.6), to insufficient food availability, such as a food desert (National Coalition for the Homeless, 2011), to lack of proper nutrition education (Dollahite, Olson, Scott-Pierce, 2003, Pg. 138-139), and even lack of awareness (Broton, Goldrick-Rab, 2018, pg.9: 129).

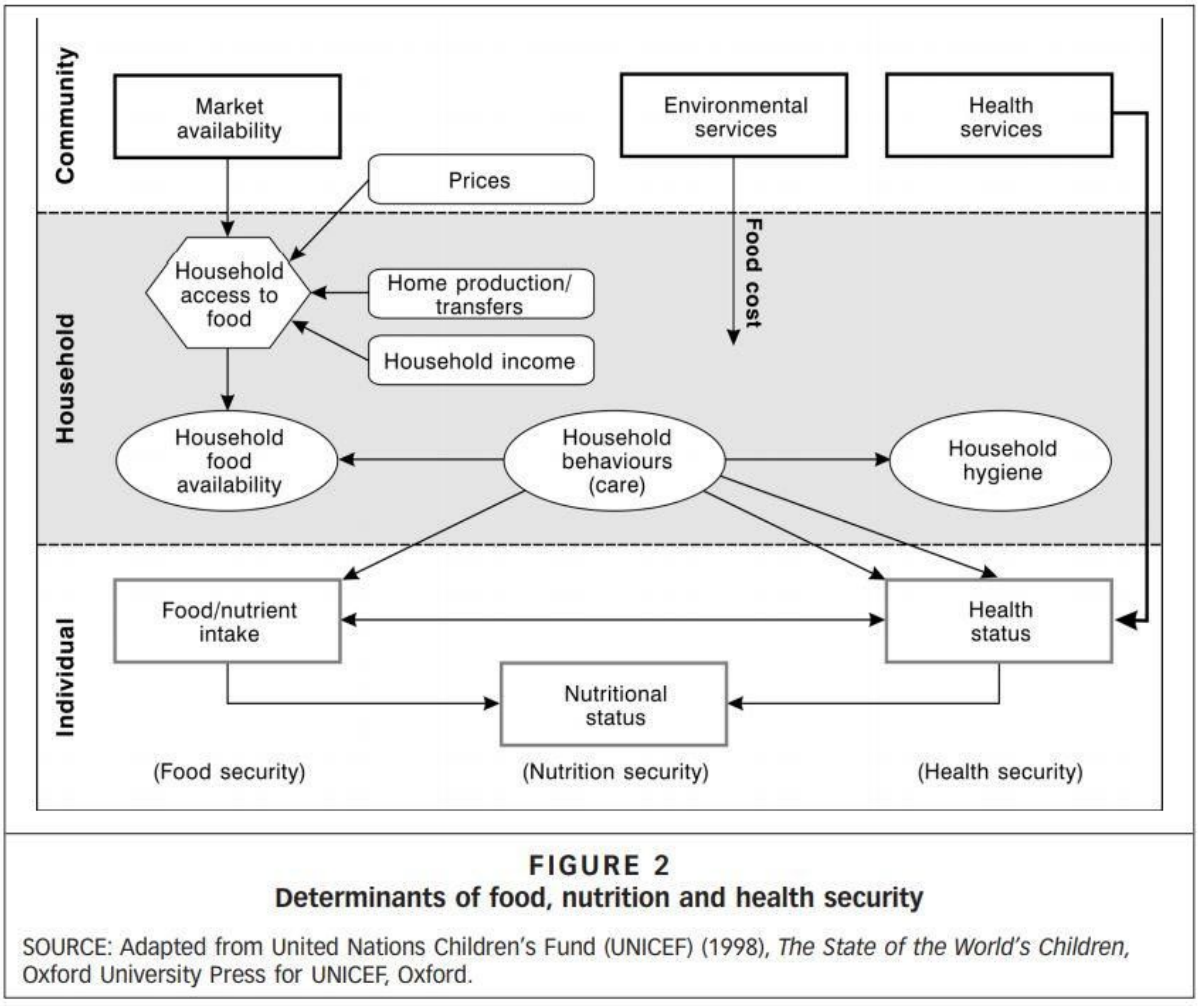

FIGURE 2
Determinants of food, nutrition and health security

SOURCE: Adapted from United Nations Children's Fund (UNICEF) (1998), *The State of the World's Children*, Oxford University Press for UNICEF, Oxford.

Figure 1: Determinants of Food, Nutrition and Health Security (Cohen, Garrett, 2010, pg. 3)

2.2.1.1. Access

If resources, such as jobs with sufficient income, make food unaffordable or unobtainable, a lack or limitation of access contributes to food insecurity (Peace Corps, 2018). Income level and poverty have influence over an individual's access to nutritional food. When an individual has a limited income the amount that can be spent on a diet that satisfies nutritional

guidelines. Additional as poverty increases the availability and allocation of resources is reduced, leading to a limitation on a nutritional diet. As the income-to-poverty ratio changes as does food insecurity rate.

An inverse relationship between income and food insecurity exists, but a large number of households above the poverty line are food insecure. This is likely because income does not solely (or adequately) represent access to food (Gundersen, Kreider, Pepper, 2011, pg. 8). In the United States, the poverty level for an individual is $12,490, and a three person family is $21,330 based on the poverty guidelines of the Federal Register by the Department of Health and Human Services (HHS). If a household has less than this amount of income they are considered to be living in poverty.

Table 2: 2019 Poverty Guidelines for the 50 States.

Persons in Family/Household	Poverty Guideline	For Alaska	For Hawaii
1	$12,490	$15,600	$14,380
2	$16,910	$21,130	$19,460
3	$21,330	$26,660	$24,540
4	$25,750	$32,190	$29,620
5	$30,170	$37,720	$34,700
6	$34,590	$43,250	$39,780
7	$39,010	$48,780	$44,860
8	$43,430	$54,310	$49,940

Recipients of food assistance programs tend to be more vulnerable to food insecurity (Holben, 2010), these programs include food pantries, soup kitchens, and homeless shelters. To receive assistance from these services, such as SNAP, an individual must meet certain criteria regarding their income, expenses, age, student status, and immigration status (USDA-FNS, 2013). To be considered a person must have between $2,250 and $3,500 in countable resources, some licensed vehicles, limited gross and net income, and certain shelter costs to name a few (USDA-FNS, 2013). That is to say, individuals who are eligible for food assistance programs must have limited resources. This could suggest that college students may not be able to receive food assistance programs due to the income of their family, so while they're in school they would not have access to the proper food. Subsequently a reported 63.4% of people receiving food assistance experienced some degree of food insecurity (Karnik, Foster, Mayer, Pratomo, McKee, Maher, Campos, Anderson, 2011, pg. 4).

2.2.1.2. Availability

Availability is marked by "the amount of food that is present in a country or area through all forms of domestic production, imports, food stocks, and food aid" according to the World Food Programme (WFP, 2009, pg. 170). Food deserts are areas in which healthy and nutritious food is not close enough to be useful or even available; the food available at gas stations, such as chips, candy, or hotdogs and soda, as opposed to super markets with produce, meat, and grains for instance. Food deserts contribute to 5.7% of causes of hunger with 75% being urban, and 25% being rural. Households without access to a vehicle are limited in where they can shop for food. There are 2.3 million households further than 1 mile, and 3.4 million are between one-half

to one mile from supermarkets without vehicle access. 11.5 million people living in low income areas are more than one mile from a supermarket (National Coalition for the Homeless, 2011).

The inability to locally grow food due to physical space or conditions is also a contributor to limited food access. These conditions generate a lack of fresh fruit, vegetables, and other healthy foods, and is an indication of a food desert by definition (Gallagher, 2011). Food availability is strongly related to income and education, as well as race-ethnicity. Low income and less-educated people tend to live in neighborhoods where availability of healthy food is lower, when compared to those with higher income and more education (Franco, Diez-Roux, Nettleton, Lazo, Brancati, Caballero, Glass, Moore, 2009). Access is also limited by transaction cost, not simply actual access or availability, such as travel to obtain food for instance. Such limitations and food deserts are likely to influence food consumption patterns (Bitler, Haider, 2010, pg. 5). As previously discussed, “low income” is associated with greater food insecurity.

2.2.1.3. Awareness

“Lack of awareness” is a contributing factor to food insecurity. If the problem hasn't been addressed by administration due to not being identified it will continue. Numerous studies have been completed regarding risk and reward of attending college for students, availability of education, and return on investment (Castex, 2017; Donovan, Herrington, 2017; Quinn,Cornelius-White, MacGregor, Uribe-Zarain, 2019). All of which look at a multitude of factors such as enrollment costs, tuition, available funds like grants and income, as well as age, race, sex, physical and mental health, and so forth. Some even look at religiousness or spirituality. One focus largely missing from studies of this nature are food security, showing this

factor is not considered for completion rates, risk, or rewards. Due to food security not being considered a factor this may explain why upwards of half of college students lack proper diets and are deemed food insecure.

The percentage of college students (as of fall 2018) that received information from their college or university about nutrition was 48%, and eating disorders was 30%. Mental health clinicians' top concerns about college student patients were anxiety (23%), depression (19.2%), relationship problems (7.7%), and stress (5.8%) (Statistia, 2018). These concerns are factors that impact an individual's choice regarding what needs they address over another. For instance, a student who has depression may not focus their needs on eating, especially if they are not properly educated on nutrition and proper diets..

2.2.1.4. Education

Education is linked directly with food insecurity, as well as awareness to food security, availability of food, and access to resources. Due to the role education plays on all these factors we consider it to be arguably the most important contributor to food insecurity.Individuals who participated in Expanded Food and Nutrition Education Program (EFNEP) have experienced positive changes in food security. (Farrel, 2013, pg.3). This is because the program educates people on food related behaviors like food-resource management, nutrition practices, dietary intake and household availability regarding healthy foods and nutrients. It also improved general health. All of which are associated behaviors with healthy dietary intake, and may improve food security.

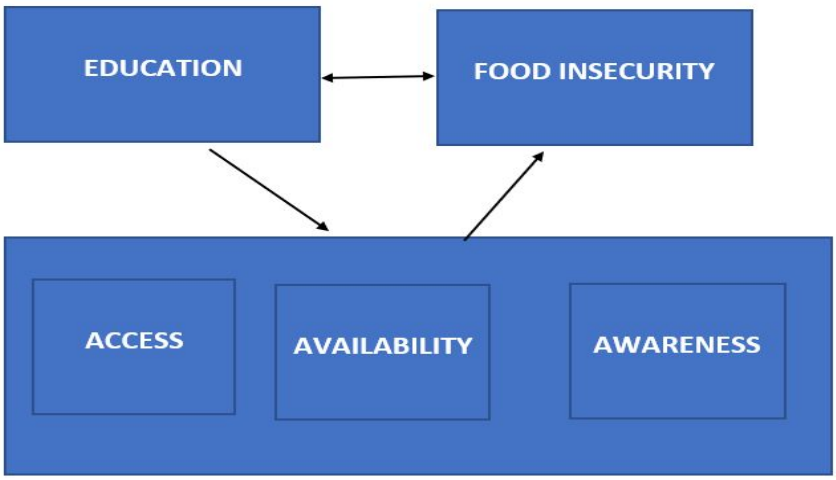

Figure 2: Illustrating the Impact Education has on Food Insecurity

It has been indicated that inequalities in health could be primarily explained by socioeconomic factors (Acheson, 1998). Persons who complete college had the best health status according to the study of health at Midlife, compared to high school graduates with some college education. People who didn't complete high school had worse health than the other two groups (Grim, Ryff, Kessler, 2004). This measure was based on psychological well-being, physical health, and an objective marker of disease risk (waist-hip ratio).

Women who complete college are 8.5 times more likely to have better health compared to those who did not complete high school. Individuals with higher levels of poverty, lower education, lower income, and socioeconomic status were more likely to have poor health, and a depression diagnosis (Grim, Ryff, Kessler, 2004). Certainly the greatest group of people at odds for poor health are those who did not complete highschool, as indicated above. Those who only complete some college are over 2.5 times more likely to have poor health. The findings above are similar for men as well, although the likelihood for poor health for non-high school graduates

is lower (6.1), and some college education is 2.07. Household income is greater as well, at 4.31 and 1.64 respectively.

As the level of education of both men and women relates to poorer health, looking at the contribution of those levels towards a child's personal likelihood to experience poorer health is also appropriate. It was shown that a mother's education does have an impact on their child's health, although this contribution was less significant than personal education as the child reaches age 15 (Karki Nepal, 2018; Apouey, Geoffard, 2013). Along with being associated with better health and lower rates of poverty for a family, individuals that are college educated tend to have better labor market outcomes, as shown by various studies (Castex, 2017).

Education is linked with income (Wolla, Sullivan, 2017), increasing from 1.85 to 1.5 times with each level of education. Income is linked with social class - it is worth noting that class is also "other forms of health-relevant social inequalities" (Coburn, 2004, pg.3). Additionally education also has a relationship with class, placing it at the center of social class to ensure privileges or disadvantages (Archer, Hutchings, Ross, 2005, pg.5). This stands to show that a lower education not only results in lower income, but also lower social class status, and could be argued that inability to gain a higher education due to cost creates a greater social class gap. As social class is linked with income it may be safe to say while there is financial help for the working and middle class this does not fully alleviate financial burdens regarding food insecurity on the vulnerable.

As there is a link between food insecurity and education outcomes, as well as income and health outcomes. Due to the multiple outcomes, it is especially important to address the problem of food insecurity for vulnerable students while in school. This is because an educated student is

more likely to be healthy, financially secure in a stable job, and thus more food secure later in life.

2.2.2. Maslow's Hierarchy of Needs

Maslow's Hierarchy of Needs is a model that seeks to explain how human needs influence behavior. It was outlined originally in Abraham Maslow's book "A Theory of Human Motivation" (1943), and further amended later in "The Farther Reaches of Human Nature" (1993). This is a framework that helps to explain how humans react to stressors and achieve what is called self-actualization. It will allow for insight into how food insecurity impacts individuals, especially college students. Each need listed, as seen in the figure below and description below, all contain smaller subsection relating together. Each tier contains sub-needs, exemplifying the overall tier they lie in, which are not necessarily required to survive or live. The higher tiers above physiological needs are not essential for existence, in that a person is able to live without them, but the quality of their life is subject to danger, isolation, and limited to a basic understanding of and contribution to the world we live in.

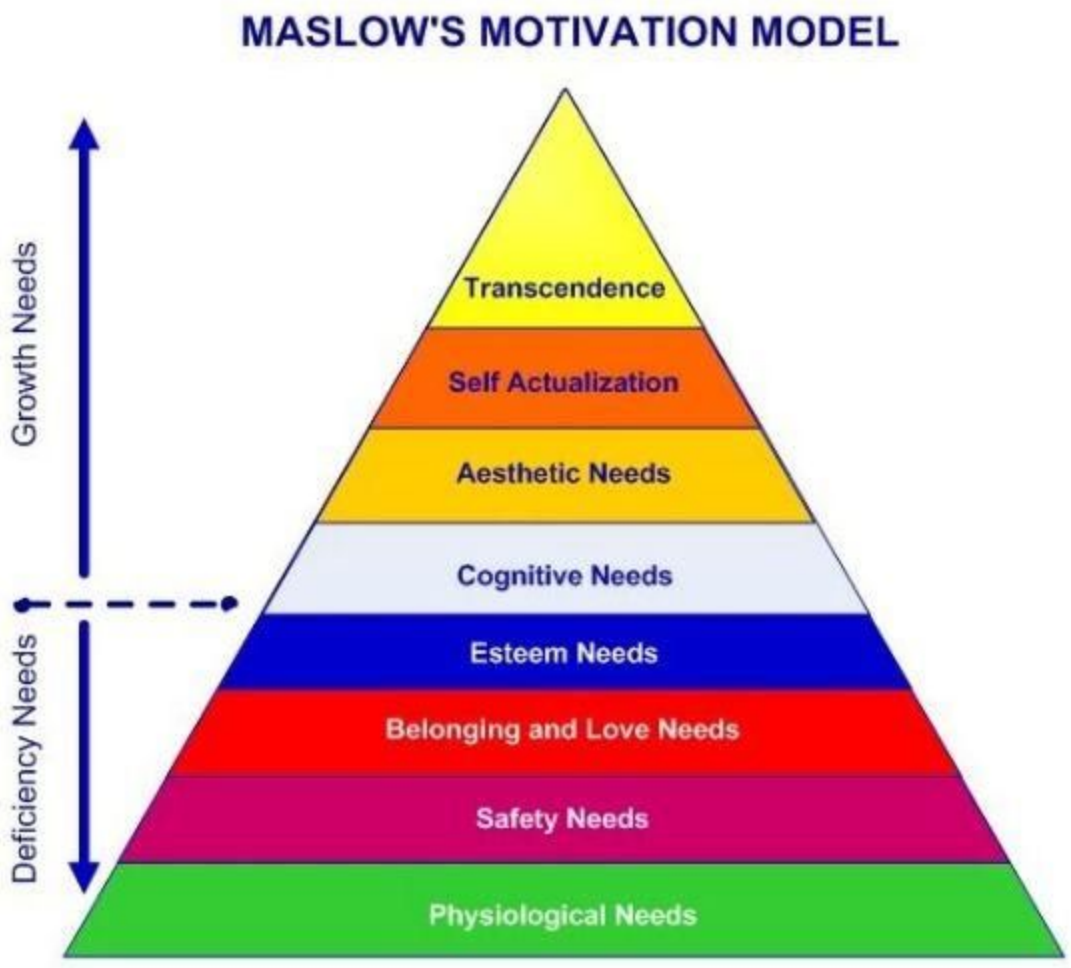

Figure 3: Maslow's Hierarchy, Including Amended Tiers (McLeod, 2018)

Physiological needs, for instance, are at the base of the pyramid, and include eating, drinking, sleeping, air, shelter, and warmth (Huitt, 2007, pg. 1). The table below gives examples of what each tier includes.

Table 3: Details of Each Tier of Maslow's Hierarchy of Needs.

Growth Needs	*Transcendence*	Connection beyond ego, or helping others realize their potential
	Self-Actualization	self-fulfilled, realizing own potential
	Aesthetic Needs	Order, beauty, symmetry
	Cognitive Needs	knowledge, understanding, exploration
Deficiency Needs	*Esteem Needs*	competency, recognized, have others approval.
	Belonging Needs	Affiliated with others, accepted.
	Safety Needs	Out of danger.
	Physiological Needs	eating, drinking, sleeping, air, shelter, warmth.

Moving up the tiers of the needs the necessity for life is further diminished, instead they foster growth, a nature of thriving, and improvement for individuals. At the two highest tiers, self-actualization and transcendence, the needs include one's realization of personal potential, self-fulfillment, and motivation beyond person self. For a person to achieve self-actualization and transcendence prior needs must be met. It's been shown that someone could live in poverty but still realize their potential such as Ghandi for instance, so it is not true to say later needs cannot be fulfilled unless the entire list of previous needs are. It is true to say that longer a need goes unfulfilled, like eating, the more attention it will require eventually. To fulfill any need attention and energy must be diverted from other needs.

"[A] peculiar characteristic of the human organism when it is dominated by a certain need is that the whole philosophy of the future also tends to change. For our chronically and extremely hungry man,… life itself tends to be defined in terms of eating. Anything else will be defined as unimportant. Freedom, love, community feeling, respect, philosophy, may all be waved aside as fripperies that are useless since they fail to fill the stomach.

All that has been said of the physiological needs is equally true [of the safety needs]…. Again, as in the hungry man, we find that the dominating goal is a strong determinant not only of his current world-outlook and philosophy but also of his philosophy of the future." (Maslow, 1943, pp. 374-376)

As an individual looks to fulfill higher tier needs the former needs must be satisfied, otherwise the higher needs become increasingly difficult to fulfill. Developing socially-emotionally, self-actualized humans is the primary goal of the education endeavor, which is contained in the highest tiers of Maslow's Hierarchy. Yet if the lowest tier needs are not secured, such as food, it becomes nearly impossible for an individual to achieve self-actualization. Not fulfilling basic needs impedes the fulfillment of other needs, all of which are required to grow physically and as an individual. This is also supported through medical science and research (Olson, 1999), in that if someone is getting insufficient nutrients in their diet they will be less physically and mentally healthy.

2.2.3. Food Insecurity Impacts

2.2.3.1. Food Insecurity Impact on Health

Food insecurity results in poorer nutrition (Robaina, Martin, 2013), and poorer nutrition leads to poorer physical health such as obesity (Olson, 1999). Poor nutrition is also linked to the degradation of mental health, and when mental health declines poor dietary and nutritional choices often emerge (S. Rao, Asha, Ramesh, J. Rao, 2008). It's notable that the decline in dietary choices mirrors the definition of food insecurity, which may be contrary to food availability and accessibility in certain situations. The case of a decline in mental health leading to poor dietary choices would be more of an example of oversight, relative to Maslow's Hierarchy as an individual wouldn't be fulfilling their basic need - rather they are fostering a psychological need to some effect.

Poorer mental and physical health correlate to lower academic performance, although the direct causal link between physical health and academic performance is difficult to ascertain, as there are many measures that cannot be easily consolidated into a single factor (Ding, Lehrer, Rosenquist, Audrain-McGovern, 2009). These measures are things such as blood pressure, heart rate, BMI, and similar factors. Instead health behaviors are often considered, like exercise, smoking, drinking, and so forth. It is worth noting that obese children have been shown to have a lower GPA than their peers (Ding, Lehrer, Rosenquist, Audrain-McGovern, 2009, pg.11). Community college students not only seem to be at greater risk for food insecurity but those who are impacted by it are more likely to fall into a lower GPA category (2.0 to 2.49) rather than the highest category (3.5 to 4.0) (Maroto, Snelling, Linck, 2014, pg.9 and 10).

It has been concluded that children with mental health problems are less likely to succeed in school. Whether these mental health problems already exist or develop they contribute to the likelihood of failure or dropout. Further complicating the relationship between mental health and academic performance. Compounded with this fact, individuals who fail or dropout are at greater risk for poorer mental health outcomes (DeSocio, Hootman, 2004, pg. 3). This appears to be due to the necessity of addressing mental health issues as they develop, and to do so in ways that don't deviate from daily routines or normative environments. This positions schools to provide improved utilization of these services. Consequently, 70% of children who require and receive mental health services identify school as their primary source of mental health services (DeSocio, Hootman, 2004, pg. 3). While this study focused primarily on K-12 students it is relevant to note as these health issues affect these individuals throughout their life.

"The proportion of youth with mental health problems has continued to increase, with an estimated 21% of America's children, ages 9 - 17, affected by a mental health or an addictive disorder (U.S. Depart-ment of Health & Human Services [USDHHS], 1999). Furthermore, mental health disorders that emerge during childhood are likely to persist into adulthood, seriously compromising quality of life and human potential (USPHS, 2000)." (DeSocio, Hootman, 2004, pg. 2)

As stated previously ,mental health issues can lead to further impacting dietary choices, creating greater food insecurity alongside a reduced level of education. This goes on to further exacerbate the underlying issues. There is a compounding relationship between food insecurity, decreased health, and hindered education which stands to further the vicious cycle of poverty.

Stressors are things that create stress, such as being hungry, tired, or having to finish a report for school. When presented with stressors an individual must allocate resources (time, energy, and so forth) to address and reduce them to satisfy the need they are related to. These stressors can also come from situations; financial stress is reported to hinder upwards of 60% of people (Statistia, 2018). To combat this stress people develop coping mechanisms such as growing their own food for instance, finding alternative sources of food, or limiting their consumption by amount or variation for instance. This also includes mechanisms that are not healthy or conducive to a proper, balanced diet (Feeding America, 2018).

2.2.3.2. Food Insecurity Impact on Colleges

Food insecurity impacts colleges through the students attending the institution. With completion rates of students currently around 50% to 55% (Castex, 2017), and retention of students being an institutional goal, ensuring students complete their program is certainly an area of interest for the college.

"The top three academic experiences reported by food-insecure students were difficulty concentrating in class or on an exam (73%), inability to study for an exam (23%), and inability to complete an assignment (15%).. Students experiencing food insecurity were more likely to fail courses or refrain from registering from future courses... food insecurity can increase psychological distress and worsen mental health, which can directly and indirectly affect academic performance. In addition to the psychological mechanisms, this study has further highlighted physical mechanisms by which food insecurity can affect academic performance, including a lack of energy caused by not consuming enough food or the right foods, the

distraction of one's stomach growling in a small classroom, and sleeping to cope with hunger. " (Meza, Altman, Martinez, Leung, 2018).

Over the past six years undergraduate college enrollment has declined, and is projected to drop significantly over the next six years (Murray, 2019). Since the food insecurity of students impacts colleges, the institution should support the basic needs of students.

2.2.4. Summary of Food Insecurity

On the surface It's not so clear that food insecurity is a big problem. Seemingly it is only a small scale problem when in reality it is a worldwide problem. it seems to be only a trivial problem because the ripple effect convolutes the problem with - health, economics, education, etc. Logically, one could say that food insecurity is a detriment to the advancement of the human species. Fortunately This fact is not entirely bad news because it means that by solving this single issue of food insecurity, advancements to the human species could be "advanced in one bound".

Food insecurity is a big problem in plain sight, that many people are seemingly unaware of. In Massachusetts around 50% of the college student population experiences food insecurity. With a population of 6.5 million people in the entire state, 1.43% of those are students with this problem. Although this seems like a small amount of people relative to the entire population, the reality is that nearly 93,000 students are affected. Out of the projected 19.9 million college students in 2018, and using the lower percentage of 25%, there are at least 4.9 million students facing food insecurity.

As food insecurity has a complicated nature through its cause and impact it's safe to say there isn't one sole solution. Rather it can be addressed at multiple levels; food pantries or programs, humanitarian efforts, addressing changing environments and climates for instances. With any of these efforts, education is tantamount to the success of any endeavor to address food insecurity. If that education can be involved, fun, benefit people who are affected by the problem and the community, and additionally address more than one issue at once (education and food insecurity), there is potentially a much higher chance of improvements. This can be done by addressing the problem in the moment and creating a long lasting change to societal livelihood, A greenhouse is an example of a potential tool to address food insecurity on a college campus.

2.3. Greenhouses

Greenhouses have been used for centuries to grow food, whether for optimal growth or to combat plant specific environmental constraints. A greenhouse works by creating a controlled environment, often through technology for temperature, light, nutrients, and water regulation. A major benefit of a greenhouse is that the temperature inside is greater than the temperature outside, allowing for plants to be grown year round, even in cold climates. Greenhouses not only help combat against cold temperatures, snow, or over-watering, but also against both animal and insect pests. Greenhouses also allow for optimal growth requirements, meaning a plant will get exact sunlight, food, and water needed to not only grow, but thrive passed what is likely outside, in an open environment.

Different greenhouses are characterized by the level of protection from the outside environment they can offer and the capability they can provide growers to control the inside environment to a specific set of conditions (Morgan, 2017). This enables greenhouses to be used in any climate as long as the design it taken into account. Being in such a controlled system further allows for an improved understanding of what these plants require, essentially enabling the hacking of plant behavior to go beyond what would normally be possible with regard to their growth.

2.3.1. The Greenhouse Effect

A greenhouse utilizes a process called the "greenhouse effect" in order to keep crops warm in colder climates. In fact, the same process is how our planet keeps itself warm in the cold environment of space. Just as the Earth has an atmosphere, a greenhouse must have a penetrable layer (usually glass or clear plastic) that lets the sun's energy pass, but the layer must be able to hold that energy inside without escaping. This is the main advantage of a greenhouse; to be able to have an enclosed area that can contain heat from the sun no matter the temperature outside. (Doyle, 2019)

More specifically, the greenhouse effect uses three different wavelengths from the sun's energy. Long-wavelength infrared light, short-wavelength infrared light, and visible light. The long-wavelength IR light can't pass through the greenhouse walls because it has a low frequency which isn't powerful enough to pass through glass or clear plastic. The short-wavelength IR light has a high frequency so it is powerful enough to pass through the material of the greenhouse walls. Then there are different wavelengths of visible light which can all enter the greenhouse

and is needed by the plants for photosynthesis. Specifically, plants absorb blue and red light energy. (Nagaraja, 2010) And reflect green light, causing plants to look green. (Biggs, 2008) Plants have been shown that they need short-wavelength IR light in order to bloom too. When short-wavelength IR light enters a greenhouse, it hits either plants or other materials like the floor mostly. The plants and floor reflect this short-wavelength IR light as long-wavelength IR light. As noted earlier, the long-wavelength IR light cannot penetrate the greenhouse walls so now that it is inside the greenhouse, it cannot escape and keeps reflecting off different plants, materials, and walls in the greenhouse. (Griesmer, 2013) This creates a lot of energy known as heat which is what keeps the greenhouse warm. This is how the Greenhouse stays warm, by trapping the long-wavelength IR light which then creates heat as a result of its energy staying in the greenhouse. The only light that then escapes the greenhouse is the mostly green visible light since most of what you see in the greenhouse are green plants which do not absorb the green light and so they reflect green light making plants look green to the person looking at the plants.

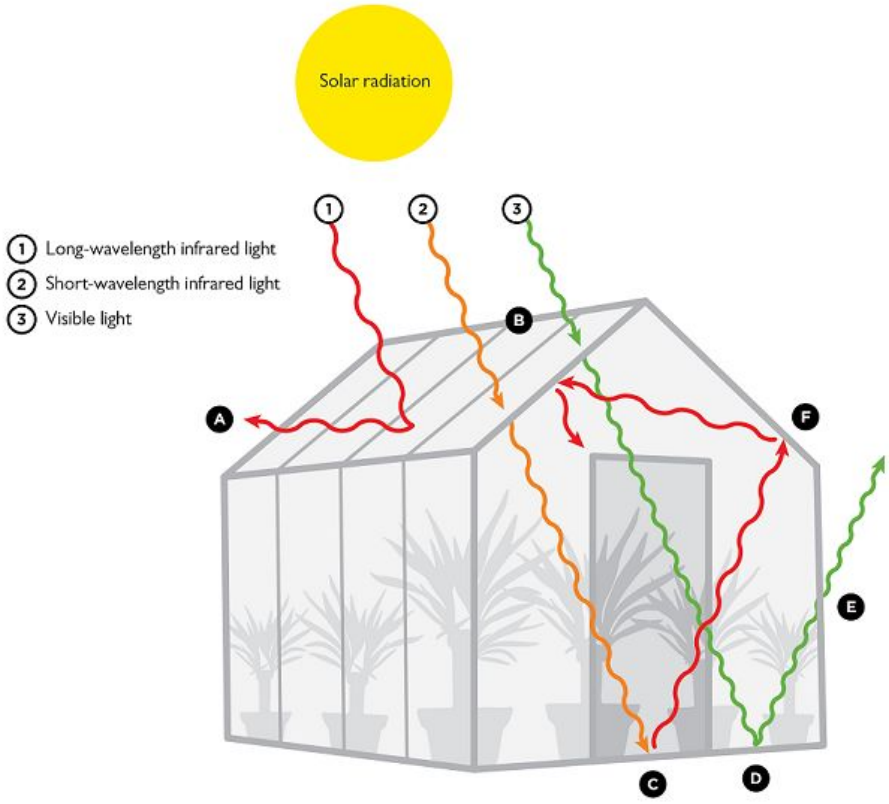

Figure 4: Diagram of Greenhouse Effect Process (Griesmer, 2013)

2.3.2. Sustainability and Optimization of Greenhouses

The main purpose behind growing crops in a greenhouse is to maximize crop production by increasing the growing season and regulating temperature. Heat retention and temperature regulation is the primary job of a greenhouse and occupies most of the design considerations required to build a greenhouse. We would like to design a greenhouse that is both sustainable and optimized in order to maximize crop production as much as possible. To do so we will carefully consider these goals along with any other criteria that presents itself along the way for designing a functional greenhouse and we will explore the best ways of fulfilling them.

2.3.2.1. Heat Retention

Not all “trapped” heat stays trapped in a greenhouse but instead slowly leaks out the same way heat leaks out of a house during cold weather. Therefore additional methods must be used to further retain heat. Any solid object inside your greenhouse will absorb heat and release it slowly over time. This phenomena is good because it can provide heat at night when the temperature drops and the sun is no longer providing an outside heat source. Carbon dioxide is also a good heat absorber and can be increased in a greenhouse when used in combination with proper ventilation (Martin, 2014). Another well known method for retaining heat is by simply insulating your greenhouse. Depending on where the greenhouse is built, not all the sides of the greenhouse need to be letting light through because some side(s) are not exposed to direct sunlight and cannot let concentrated light through anyway. Any part of the greenhouse that does not serve to let light through can be walled off and insulated. The sides that let light through can be optimized to retain heat by using “a better type of glazing with lower reflectivity, absorptivity, and heat loss coefficient” (Martin, 2014). Double or triple glazing layers can reduce heat loss significantly. A double glazing will reduce heat loss about 30% more than a single glazing and a triple glazing can cut the cost in half. Initially, extra glazing is costly but it can pay itself off in one or two years ("Home Gardening Experts", 2001, page 24). One way to optimize the roof in order to utilize the sun’s rays as much as possible is to angle the slope of the roof exactly perpendicular to the sun’s rays. To optimize light retention for the entire greenhouse, face the front of the greenhouse directly in the middle of the sun’s path from rising to setting. For New England, this

direction would be facing south with the lengthwise sides of the greenhouse facing east and west. In this position more surface area of the greenhouse is exposed to the sun's rays.

As was already mentioned, Solar heat can be absorbed, stored, and then radiated slowly over time. A body of water in the greenhouse can absorb heat from the sun quite well and can store a lot of heat. For example, 55 gallons of water heated to 70 degrees fahrenheit will store about 1000 Btus of usable heat that can be given back to the greenhouse at night. Rocks, bricks, and concrete, although they cannot store the quantity of heat that water does, do store some heat. They store about one third of the amount of water, and can also double as a floor. One thing to remember about these types of floors is that they need insulation beneath them otherwise heat can be lost through conduction. Glauber's salt and calcium chloride hexahydrate are more heat storing materials. Normally contained in plastic or stainless steel tubing, these materials change from solid to liquid phase at about 85 degrees F and can store considerable heat in this phase change. The heat is released at night as the greenhouse cools. An advantage to using materials like these is that they can conserve space. Passive heat retention systems are excellent for sustainability ("Home Gardening Experts", 2001, pages 24, 27).

2.3.2.2. Artificial Heating Systems

In the cold weather, there are numerous ways to heat a greenhouse artificially. Electrical and gas heaters can be used to heat a greenhouse and with a thermostat, the temperature can be controlled. Thermal heat systems can be utilized as well. If a nearby building has a boiler system, the piping network could possibly be expanded to heat the greenhouse. Artificial heating methods are very controllable but the downside to them is that they use artificial energy which is

costly. Passive methods for retaining heat like the ones already mentioned are good for reducing energy costs ("Home Gardening Experts", 2001, page 26).

2.3.2.3. Cooling a Greenhouse

Greenhouses are primarily meant to retain heat but during hot summer months, a greenhouse might just be a little too good at retaining heat. Just like plants can't survive temperatures that are too cold, they can't handle too much heat either. Cooling a greenhouse is simple for the most part. One of the best ways to reduce heat is by blocking sun rays. This can be accomplished by covering the roof with shade cloth, using retractable blinds, or by using a spray on shade compound. Vents in the sides and roof are another simple way of letting heat out. Fans provide better temperature control than vents. An in-take fan at one end of the greenhouse and an exhaust fan on the other end is a typical fan cooling system. Evaporative cooling is another technique which could work well if fans are in place. All that is needed apart from fans in order to do evaporative cooling is to wet down the floor and/or other surfaces ("Home Gardening Experts", 2001, pages 28, 29).

2.3.2.4. Automated Watering Systems

The fresh produce that comes from a garden or greenhouse can be very rewarding and days spent planting and harvesting can be fun; however, it is easy to underestimate the actual amount of work it takes to keep plants alive and thriving. During the warmer seasons, keeping plants sufficiently hydrated is important. At the same time, watering is a time consuming task and it can take hours just to water plants, which should be done twice a week. Automated

Irrigation, as the name implies, is a system that automatically waters plants. There is no need to even turn the water on as it works with an automated switch that is triggered by a timer or some other sensor type trigger. There are many ways to automate an irrigation system and The amount of automation is adjustable. A few ways include automating plants to be watered, and automating how much water to give them by adjusting the watering time, by adjusting the water pressure, or by doing both ("Greenhouse watering systems", n.d.).

Drip Irrigation systems are no doubt the most popular irrigation systems used in greenhouses. In this system Water is delivered directly to the roots of each plant by means of a drip nozzle. The drip nozzle is imbedded under the soil right at the root network of each plant and connects via a hose spicket or can even be directly connected to the buildings water supply pipeline network. Collecting run-off water from gutters is one sustainable water source and the drip system as well could potentially be connected to the barrels and containers that collect the run-off water. There are also drip hoses that lie on the surface of the soil and weave in and out amongst the plants while water slowly drips through the sides of the hose. No matter which drip system is used, weather its a drip hose or a drip nozzle, pipes and hoses can be conveniently run in any fashion to any desired place of the greenhouse. It can even be strung up and connected to plants hung from the ceilings. Probably the biggest benefit of this type of system is that it is extremely efficient as no water is wasted. It is also simple and relatively easy to install. If one is new to the system or planting in general, it would be advisable to start by hooking the system up to only one plant or at least only a small number of plants so that if a mistake is made, minimal damage is done. Most of the time plants are underwatered but it is also possible to overwater a plant. Most commonly a timer is used to regulate the watering intervals and watering duration.

More modern systems use a sensor that senses how dry the soil is in order to determine the precise amount of water the plant needs. This technique is very useful as it is a dynamic system and surprisingly is not very expensive; however, with it a computer is involved and requires a little bit of technical skill (“Greenhouse watering systems”, n.d.).

Misting irrigation systems imitate the effects of the light rain found in nature. It is a best practice to install the misting nozzles about six feet above the plants being watered. Apart from the nozzle type and where the nozzle is installed, installing a misting system is not much different from installing a drip system. A major downside to this system is that everything surrounding the plants becomes wet and additionally in the process water is wasted. The misting system fortunately has a few redeeming qualities. The mist provides humidity to the air and it also helps to cool the greenhouse. This system may not work so well if it wastes too much water or if getting everywhere wet is too much of a hassle for students and other patrons in the greenhouse. On the other hand it could be very useful for maintaining coolness and humidity during hot weather. It might also be effective for watering a larger area with less hoses and pipes. The case could even be that it mitigates the amount of water plants need because of the coolness and humidity that it provides by means of evaporative cooling ("Home Gardening Experts", 2001, page 29). (“Greenhouse watering systems”, n.d.)

Capillary matting works based on the principle of osmosis. Special sponge like mats made of thick cotton or polyester fabric that are highly absorbing sit on trays below the plants and the soil absorbs water from them through osmosis. This system is technically not automated but instead uses osmosis as a natural way of “automatically” watering (“Greenhouse watering systems”, n.d.).

One specialized technique usually used in larger greenhouses employs the use of a boom mounted on rails that moves along a path from plant to plant or from bed to bed at a constant rate and disperses a mist over the plants. In this case, the rate at which the boom moves determines the amount of water the plants receive (Boom Irrigation, 2013).

2.3.2.5. Hydroponic Gardening

Hydroponic gardening is a more specialized way of growing plants than traditional gardening and is not as common either. Despite its rarity, it is still a viable option for growing plants and could be useful as an alternative or additional way to grow plants to help fight food insecurity. Hydroponic gardening is useful for growing plants in a limited space or in a building where it is not convenient to use soil. Hydroponic gardening mostly deals with using specially fertilized water instead of soil. In many cases the hydroponic fertilizer provides different nutrients that are unique to certain plants. The use of specialized nutrients that are unique to different plants often increases their productivity. As a consequence of water providing a less stiff growing base than soil, sometimes a structure such as an aggregate of rocks must be used to support the roots and stock of plants or keep them growing in the right direction. Typically plants are grown in a "grow tray" and nutrients are dripped onto the root system from a reservoir with a pump. In some instances a mist provides moisture and nutrients to the plant's roots which hang freely in the open air. This is risky however because there is a potential for the roots to dry out if the misting cycle is not timed correctly. Another benefit of growing hydroponically is that there is no need to use the pesticides that would normally need to be used with soil. On the flip side, one must take caution against bacterial contamination in the water. A downside to hydroponic

growing is that the specialized fertilizer is for the most part more expensive than traditional fertilizers used in soil ("How do Hydroponics work", 2019).

2.3.2.6. Using Aquaponics

"Aquaponics is a combination of aquaculture, which is growing fish and other aquatic animals, and hydroponics which is growing plants without soil. Aquaponics uses these two in a symbiotic combination in which plants are fed the aquatic animals' discharge or waste. In return, the vegetables clean the water that goes back to the fish. Along with the fish and their waste, microbes play an important role for the nutrition of the plants. These beneficial bacteria gather in the spaces between the roots of the plant and converts the fish waste and the solids into substances the plants can use to grow. The result is a perfect collaboration between aquaculture and gardening" (North, 2016).

Aquaponics are very similar to hydroponics with basically the only difference being that fish and other aquatic animals are used to fertilize the plants. As in the case with Hydroponics, Aquaponics is a specialized and less used way of growing plants but it is also a viable way of growing plants for food insecure students especially given its sustainable nature. As long as the aquatic animals are fed, the plants are fed. With aquaponics it is vital to closely monitor the PH of the water to keep it within a certain range. If the PH is too high or too low, either the fish, plants, or both will suffer. A good neutral range for the PH is between 6.8 and 7.2. To adjust the PH, use aquaponic PH adjusters which can be acquired from aquaponic gardening suppliers. The fish do not like sudden PH adjustments therefore when adjusting the PH, do it gradually. The types of fish used in aquaponic systems are fresh-water. The most popular are tilapia fish and

barramundi fish since they tolerate many diverse conditions and they grow fast. Trout-good for lower water temperatures, as well as snails and shrimp are also good aquatic animals. The best vegetables to grow in aquatic systems are vegetables that don't require a lot of nutrients and include "Lettuce, kale, watercress, arugula, decorative flowers, mint, herbs, okras, spring onions and leek, radishes, spinach and other small vegetables. Cabbage, tomatoes, cucumbers, beans, broccoli and cauliflower can require more nutrition and a well stocked or more advanced aquaponic system. Avoid growing plants that need acidic or alkaline water, because those levels of pH can definitely harm the fish (North, 2016)."

2.3.3. Optimal Plants for Food Insecurity in a Greenhouse

While any plant could probably thrive better inside of a greenhouse than outside of one, for the purpose of growing plants to feed students, the focus is primarily on bulk and nutrition.This is because students who are food insecure require quantities of quality food rather than food which may be more exotic or interesting to grow, but which doesn't provide much in the way of necessary nutrition and substance. An effective way to measure the bulk of the food produced by a given plant is to research the number of calories provided by different, average sized fruits and vegetables, as well as the rate at which a given plant grows, how fully the fruit of the plant often develops, and how often death or wilting before maturity occurs for that plant. A comparison of the number of calories produced by the different plants, and the rates of growth for different plants then reveals which are the most productive plants to grow. Next, a determination of the necessary calorie intake of the average adult yields an approximation as to the number of edible calories to try to get out of the greenhouse. This information then further

enables the intelligent selection of the plants to be grown in the greenhouse. One other important aspect to consider is the nutritional variety and density within the different fruits and vegetables being considered for growth, how this variety and density compares between the plants, and how they would help to fulfill the daily nutritional needs of an adult.

The necessary daily calorie intake of an adult can vary based on age, gender, and activity levels. The lowest required intake for a sedentary adult female (the low end of the calorie requirement) is about 2000 calories, while the highest required intake for an active adult male (the high end of the calorie intake) is about 3200 calories. (Zelman, 2008)

In 2018, QCC had 7,368 students, forty two percent of whom were male. They had 89 male students below the age of eighteen, 2688 male students between the ages of eighteen and thirty, 595 male students above the age of thirty, 173 female students below the age of eighteen, 4188 female students between the ages of eighteen and thirty, and 1037 female students above the age of thirty. Based off of these figures, the average required daily intake of an adult at QCC should be roughly 2357 calories. ("U.S. News and World Report", 2019)

The nutritional requirements of an adult are laid out in the following table:

Table 4: Amount of Specific Vitamins & Minerals Required Daily, Per FDA (Lama, 2019).

Vitamin	Amount / Day	Mineral	Amount / Day
Vitamin A	5,000 IU	*Calcium*	1,000 milligrams
Thiamin (vitamin B1)	1.5 milligrams	*Chloride*	3,400 milligrams
Riboflavin (vitamin B2)	1.7 milligrams	*Chromium*	120 micrograms
Niacin (vitamin B3)	20 milligrams	*Copper*	2 milligrams
vitamin B5	10 milligrams	*Iodine*	150 micrograms
Vitamin B6	2 milligrams	*Iron*	18 milligrams
Biotin (vitamin B7)	300 micrograms	*Magnesium*	400 milligrams
Folate (vitamin B9)	400 micrograms	*Manganese*	2 milligrams
Vitamin B12	6 micrograms	*Molybdenum*	75 micrograms
Vitamin C	60 milligrams	*Phosphorus*	1,000 milligrams
Vitamin D	400 IU	*Potassium*	3,500 milligrams
Vitamin E	30 IU	*Selenium*	70 micrograms
Vitamin K	80 micrograms	*Sodium*	2,400 milligrams
		Zinc	15 milligrams

One way to achieve bulk may be to research and grow crops which do well in the same environment. For example, if all of the plants in a greenhouse favored more heat and humidity, then setting the greenhouse up in such a way as to create a hot, humid environment would benefit every plant in the greenhouse, and thus produce a greater abundance of food from each plant.

It is important to grow plants which not only complement the other plants in the greenhouse, but also does not negatively affect each other's growth. This means ensuring that

certain of the plants do not shade other plants in the greenhouse too much, or crowd the other plants out by spreading into or over them. In general, ideal plants to grow in the greenhouse are plants which grow quickly, produce a good quantity of nutritious calories, can endure some hardship without wilting and dying, and are as compatible as possible with the other plants in the greenhouse. ("Old Farmer's Almanac", n.d.)

A set of plants which are all of the same species include broccoli, cauliflower, cabbage, kale, rutabaga, and turnips. These all thrive in cool weather, and when grown outside are considered spring and fall crops. They all grow best in neutral to slightly acidic soil. Each and every one of these plants is well known for being very nutritious, and turnips are especially promising since they can be planted close together, grow quickly, and can be entirely consumed (in other words, both the leaves and the roots can be eaten.) The downside to planting these together is that they all require similar nutrients and would be competing for them in the soil. This difficulty can be circumvented by planting the different types of plants in separate containers. Unfortunately, they also tend to be susceptible to similar diseases, which means that the introduction of such a disease into a greenhouse full of these plants could be more devastating than usual. The suggested method of mitigating this hardship is to plant other crops nearby which will help to fend off certain insects, or create a more nitrogen rich environment which enables healthier plants. ("Old Farmer's Almanac", n.d.)

Other commonly grown plants include pole beans, squash, and cucumbers. These plants have disadvantages, however, in that the beans climb to great heights and become leafy, with the result that they shade the plants growing around them. The squash and cucumbers, on the other hand, stay very low, but they spread quickly by virtue of which they would need to be carefully

tended so as not allow them to interfere with the growth of any of the other plants. In addition, tomatoes, cucumbers, and squash thrive better in warmer, more humid temperatures than do any of the previously mentioned plants. ("Old Farmer's Almanac", n.d.)

Fruits and herbs may be considered as well. Although many fruits take a good deal of time to grow, there are some which can grow in one season, such as watermelons and strawberries. In the case of watermelons care must be taken, just as with the squash and cucumbers, that they do not spread and diminish the ability of other plants in the greenhouse to grow. Possible herbs to look into are parsley, chives, thyme, sage, basil, mint, and rosemary.

2.4. Quinsigamond Community College

Quinsigamond Community College (QCC), located in Worcester, MA, is a commuter school with over 7,263 students currently (NCES, 2019). Founded in 1963 (formerly owned by Assumption College), it has grown and continues to offer over 120 Associates degrees and certificate programs in areas such as engineering, nursing, business, information technology, and many others. Over the past 50 years it has expanded on multiple fronts, including having built a STEM specific building, the QuEST Center, in 2016 to ensure students are prepared for the ever evolving technology sector of science. Not only does QCC strive to give students the best possible education, it aims to condition them to continue their academic career at 4-year schools, with articulation agreements with other colleges like Worcester Polytechnic Institute.

In-state students pay $5,586 for tuition, and out-of-state students pay $10,530. The graduation and transfer-out rate is 19%, and the retention rate is 52% for full-time students, and

50% for part-time students. The population is 42% males and 58% female; 55% white, 12.7% black, and 4.8% Asian. The highest population is 18-19, followed by 30 and over, and the lowest population is under 18. Of the students that receive financial aid 59% receive grants or scholarships, 45% receive federal student loans, and 43% receive Pell Grants ("Academic Overview: Quinsigamond Community College", n.d.).

With many areas of focus, the school offers opportunities for student life outside of traditional classes as it's home to over 25 groups like clubs and organizations. Some of these include the Psychology Club, Pride Alliance, Criminal Justice Club, Human Services Honor Society, and Phi Theta Kappa. All of these assist in the further development of a student's academic career and personal life by helping them make connections, develop skills, use the knowledge they've gained in the classroom, and to give back to the community in many ways. Of the opportunities students can give back to the community and improve their own lives, Phi Theta Kappa has created a community greenhouse on campus with hopes to combat the localized food insecurity suffered by students.

2.4.1. Phi Theta Kappa

The active honor society on campus, Phi Theta Kappa, had beginnings starting in 1910, at Stephens College in Missouri, with 6 members, the society has expanded to 3.5 million members across the United States and sovereign nations. Phi Theta Kappa's mission is to "recognize academic achievement of college students and to provide opportunities for them to grow as scholars and leaders" ("About Us", n.d.). Every year members receive scholarships of $1.5 million, and has worked with the likes of Coca-Cola, American Cancer Society, Geico, Bill and

Melinda Gates Foundation, and W.K. Kellogg Foundation with the intention to improve the recognition of students through scholarships, awards, services, and other opportunities.

Of the nearly 1,300 chapters of Phi Theta Kappa, one exists at Quinsigamond Community College. The Alpha Zeta Theta chapter, which was chartered in 1980, starting with 11 members, as a silent chapter; no events or community service. In the past 14 years it has become a five star chapter ("Five Star Chapter Plan", n.d.), one of the most active in New England, with nearly 700 members, bringing in approximately $80,000 dollars over the past 5 years from fundraising, and contributing hundreds of collective hours annually through events. The members of society generally pick organizations they are passionate about and work with them, alongside other members, at places like animal shelters, Sherry's House, Veteran's Inc, the Honors In Action Project, walkathons, and countless others. Outside of the involvement with other organizations they have continually active engagements such as the Live and Learn Greenhouse, the Burncoat Highschool AVID mentoring program, monthly scholarship workshops, and an active food pantry.

The mission of the chapter is to promote scholarship, foster the development of leadership and service, and cultivate a fellowship among qualified students. It works with the faculty and staff of Quinsigamond Community college to further assist the college in meeting their mission, values, and goals. The honor society strives to provide opportunities for students to grow and develop individually as leaders and role models. The society and its members work tirelessly to not only make a positive impact on the campus but also in the community. The two year college completion of QCC students in 2017 was 19% ("Strategic Plan Metrics", 2018, page 5), the graduation rate of PTK students at QCC in 2019 was 77%, the rate of national PTK

members is approximately 91% (Mayers, 2018) as opposed to the 39.4% overall national completion rate (Shapiro, Dundar, Huie, Wakhungu, Bhimdiwala, Wilson, 2018). Alongside the active members, the chapter also has an emerging alumni network that allows past students to stay informed of activities and continue to contribute; continuing to contribute is very common among the chapters' members.

2.4.2. QCC's Live and Learn Greenhouse

In 2004 one of the PTK members, Mary Bailey, presented the idea of a student run greenhouse to the chapter advisor, Bonnie Coleman. Her vision was to create a place that would allow hungry students a consistent source of healthy food which would combat the food insecurity that was present on campus. While it took 13 years of tireless work, research, and commitment by Bonnie and countless members, in July of 2017 the Live and Learn greenhouse was finally built and operational. It was given the name Live and Learn for many reasons. It would be a source to ensure students could more properly live by getting the food they need to thrive and be successful; further improving their overall life. Additionally it was intended to help people learn where some of their food comes from, how to grow and take care of it, and about proper nutrition, as well as giving attention to the problem of food insecurity for others whether they suffer from it or not.

Over the past two years there has been a lot of living and learning done because of this greenhouse. Thousands of dollars worth of plants, herbs, and vegetables have been grown there, including cucumbers, eggplants, peppers, tomatoes, lemons, and even pineapples, among many others. No plants are grown without opposition from nature though. To help ensure they grow

properly the greenhouse has been stocked with insects that promote a livable environment; ladybugs and praying mantises are two examples of insects used to combat pest infestations such as aphids for example. Additionally a worm-farm was built to generate supplemental nutrients for the plants (Fong, Hewitt, 1996; “The Benefits of Worm Casting", 2016), as worm castings are a sustainable alternative to fertilizer and chemicals. This is called vermicomposting, which is done by recycling food that hasn’t been or can’t be eaten by people by putting it into a container housing soil and worms. The worms naturally break down fruits and vegetables and output compost that a plant doesn’t have to break down itself to absorb the nutrients. Not only is the greenhouse improving the lives of the students, it’s improving the lives of the plants, and giving homes to environment-positive insects, helping create a sustainable cycle of food growth.

Following the namesake of the greenhouse, learning was a huge part of the process involved. From the challenges faced to actually get approval for the greenhouse to building it was another set of challenges (especially with the limited resources and physical constraints). The greenhouse itself is in a small structure, as it is a repurposed bus stop with a door and modified windows. Internal space is very limited, and structurally it is limited as well. The roof of the bus stop could not be altered, meaning sunlight would only be able to come through the front and sides. To add to its list of limitations the structure was located next to one of the campus buildings, further reducing the amount of sunlight plants would be exposed to. To overcome the challenges of spatial limitations the members had to learn how to internally control and regulate light, temperature, and humidity.

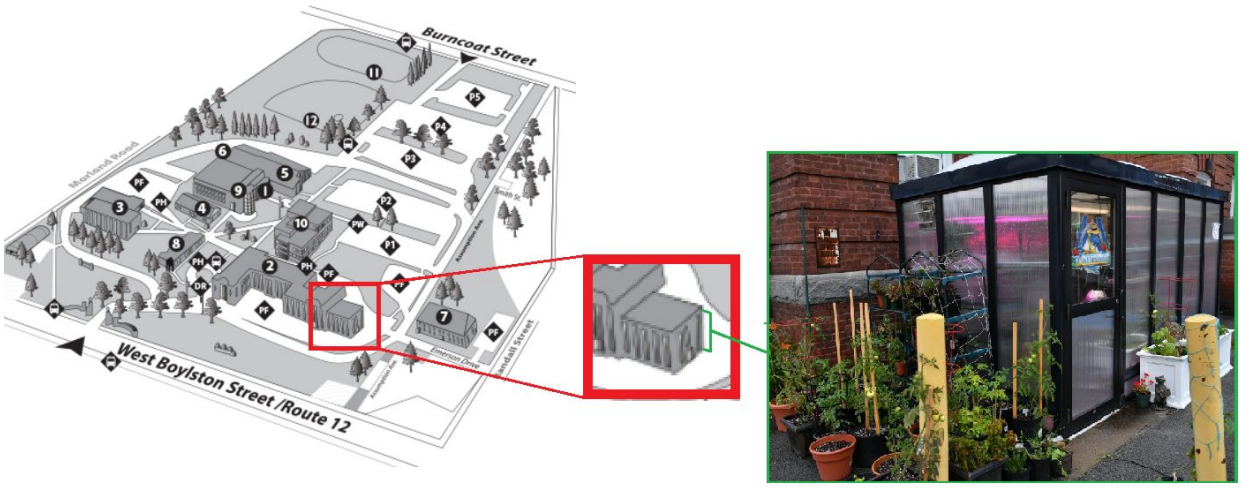

Figure 5: Diagram of Greenhouse Location on Quinsigamond Community College Campus

Faced with a list of physical challenges the greenhouse was fitted with grow lights to supplement the lack of direct sunlight, temperature and humidity sensors connected with fans and heaters, along with an automated system that assists in regulating all of those. The system was programmed by an outgoing-turned-alumni PTK member, which subsequently allowed the data to be tracked and viewed on a website (http://68.187.225.115/register). The system also included a camera, giving the greenhouse additional security and a live feed on YouTube (https://www.youtube.com/channel/UCQr67iUlB8sUwTuRsR_gk-Q). Overcoming constraints such as this, ended up becoming a costly endeavor: PTK applied for and received a grant for $16,000 dollars to be used for the entire greenhouse; of that amount they used $14.5 thousand on the windows alone. The cost for labor, equipment, furnishings, and other supplies would very quickly take care of the remaining grant money.

One of the things the chapter members are accustomed to and good at is fundraising. Fundraising is their main source of income for everything needed to run the entire chapter. The rest of the cost to build the greenhouse was raised entirely by the chapter during events they regularly hold. With this the staff of the greenhouse learned how to budget accordingly with limited funds, through buying supplies, necessary upgrades, and plants to be grown. The seeds they grow come exclusively from Johnny Select Seeds, located in Maine, which are all non-GMO, pre-pollinated fruits, vegetables, flowers, and herbs. Once their crops are grown they are logged, weighed, and put into the PTK Food Pantry for students to take as needed.

The PTK Food Pantry was opened on campus in July 2018, with the intention to provide students with food for meals at home and on campus. It also provides students with direction to connect with additional resources like food assistance and housing applications. The pantry has grown to a total of 369 clients, with around 85 weekly recurring client visits. Stocking between 25,000 to 40,000 ounces of food in the pantry at all times, alongside food from the greenhouse, the pantry stocks non-perishable items like canned fruits, vegetables, rice, cereal, baby food, snacks, peanut butter, powdered milk, and many more things.

Not only has the chapter learned how to plan and build a greenhouse to live in harmony on the campus with students and facilities, they've also learned how to efficiently run and take care of the entire workings of a greenhouse. The Live and Learn Greenhouse has been one of the largest endeavours of the chapter, which is now synonymous with Phi Theta Kappa. It will continue to be an integral part of the success of not only the students, but the chapter itself, the college, and the community through the lives these students touch.

2.4.2.1. Future of the Greenhouse

Over the next year PTK will be building a larger greenhouse, which will be 16 by 20 feet (practically 3 times the size of the current greenhouse). The current greenhouse will be used to start plants which will be transferred to the large one. As mentioned before, this greenhouse will be used to increase the amount of food grown through optimization, larger size, and more involvement. This will continue to be run by future society members as a continual expectation of responsibility, meaning these positions created will not be eliminated as this endeavor is just another part of what the chapter does. Not only will this improve the well-being of the students, but also the college, community, society, and thusly the world. Part of why this greenhouse is to be built is to show the students that the college cares about them, and its appearance is a good indication of that.

The new greenhouse will have an education program to ensure there are lessons in place that will focus and exemplify the importance of nutrition and growing our own food. Additionally greater involvement from students and administration is expected through the education plan, with the hopes of facilitating some form of project based learning for classes. Subsequently there are intentions to include a meditation garden, giving credence to the importance of maintaining not only physical well-being, but mental health as well. Teaching the students and mentees of the mentoring program how to grow their own food, and the importance of nutrition will continue to be a core mission of the future greenhouse to ensure that no student or person needs to go hungry again. With the work previously done on the original greenhouse, there is a standard being set with this project to seriously look at and consider food insecurity as

a major problem, but also one that can be combated through engagement and education and having a long lasting, positive impact on the world.

3. Chapter 3: Methodology

3.1. Introduction

We developed a plan to optimize QCC's future greenhouse in conjunction with an education program for food insecure students. In order to complete this goal, we created a series of steps based on a Most-Similar Pathway case study methodology. We explain why we chose this type of methodology, as well as what weaknesses it has and how it affects participants involved in the study. We then go through how to decide what cases to look for, finding cases, and selecting the best ones for the study. The next step was collecting data from the cases by based on what information we needed from them, contacting them to set up an interview and interviewing them to collect relevant data as well as use that opportunity to collect document and observation data. Lastly, we lay out the steps on how to analyze documents, observational data and interview transcripts. Once analyzed and discussed, we recommend to QCC what their best options are for their greenhouse.

To help us focus our steps, we have determined that there are three components to make this goal a reality. This reality is having a greenhouse that is optimized to combat food insecurity through an education plan. These three components are: optimization of greenhouses, education plans, and food insecurity protocols across communities.

Table 5 outlines the steps this methodology chapter will explain in detail followed by a summary.

Table 5: Methodology Procedure Overview

Procedures:

1. Case Study Methodology
    a. Benefits of Using a Case Study Methodology Approach
    b. Potential Weaknesses and Mitigation Methods
    c. Risks for the Participants in the Study
2. Case Criteria, Identification, and Selection
    a. Case Criteria
    b. Case Identification
    c. Case Selection
3. Data Collection
    a. Information Needed from the Cases
        i. Consent Forms
    b. Contacting Cases
    c. Document Collection
    d. Observational Data Collection
    e. Interviews with Key Stakeholders
4. Data Analysis
    a. Document Analysis
    b. Observational Data Analysis
    c. Interview Transcript Analysis

3.2. Case Study Methodology

This study utilized a comparative case study methodology with a qualitative focus to analyze community based greenhouses. This section details the benefits of the type of case study approach selected, Most-Similar Pathway methodology which is described below, along with weaknesses that were likely to emerge. Subsequently the risks for participants of the study are detailed. The steps needed to utilize the case study methodology are to identify and select the cases, collected the data, then finally analyze that data. For this process to be completed the outline in this section ensures the most beneficial cases, thus data, is identified.

3.2.1. Benefits of Using a Case Study Methodology Approach

A mixed method case study design, such as the Most-Similar Pathway case study also known as the Method of Difference, is used across multiple case studies. It allows for cases to be generated based on quantitative and qualitative factors. This is very useful for this type of project as it is conducive for comparison across these multiple cases. "This complex mixed methods design is consistent with the basic idea of a case study that focuses on developing a detailed understanding of a case (or multiple cases) through gathering diverse sources of data" (Creswell, Clark, 2018, pg. 116).

"A typical mixed methods case study design is one where both types of data are gathered concurrently in a convergent core design, and the results are merged together to examine a case and/or compare multiple cases." (Creswell, 2018, pg. 106). A convergent core design is where

qualitative and quantitative data are gathered concurrently, allowing them to be combined to examine the individual and multiple cases, this is as opposed to when data are gathered prior to or after the case study has concluded.

This approach is appropriate to achieve the goals of the study as it allowed for the flexibility to discover and explain different elements, quirks, and unique approaches of organizational structures and general greenhouse functionality by the different greenhouse programs. It allowed us to go deeper with the QCC program and then to compare their program with other programs. This encouraged similarities and differences to be discovered, identifying how they would impact a greenhouse.

3.2.2. Potential Weaknesses and Mitigation Methods

Weaknesses and limitations to our case study methodology are heavily contingent upon the stake-holders and people we interview. Time restraints and availability of key stakeholders may affect the interview process. For instance, a person may only be available at certain times while another person of interest to interview might not be available at those times. Furthermore, a person might not be available at all for one reason or another. Time restraints could also shorten the interviewing time making it harder to elaborate on questions and the overall interviewing process.

Regional and cultural factors could influence this study as well and results could vary accordingly. This is one of the many good reasons why it is important to build rapport with the interviewee, as interpersonal rapport can impact interviews. If this study is applied outside of Massachusetts, certain regional and cultural factors such as differences in growth and food

intake, may be different. Different seasons, especially with colleges, will impact availability. Answers could also be highly variable depending on the season. The weather is a big factor and the immediate circumstances will most likely be the first to come to the mind of the interviewee. Lastly, we will want to identify and select the right cases to study otherwise the whole premise of what our interview is based upon would be skewed.

When people have time restraints, extra effort is required to work with their schedule as best as possible. Being flexible with our own time and having several optional times and dates for an interview were necessary. Again building rapport with people is key for overcoming communication barriers, especially in light of cultural differences. If this study were to stretch out to other regions, taking into consideration the different food intake needs would "close that distance".

In general, being as clear as possible about what criteria we are interested in learning about will yield the feedback we are looking for. One way to ensure that we are making good choices in case selection is to align the cases with our 3 components. We detailed the three components as a way of identifying what we are looking for. As long as all three components are covered in the case studies, we should have all the information we need.

3.2.3. Risks for the Participants in the Study

We interviewed people that have information on the criteria detailed in section 3.3.1 of this methodology report and listed again below for convenience.

- A specifically designed greenhouse for optimization of their greenhouse's structure to benefit their plants for its purpose of use;

- An implemented education program on Greenhouse case and use;
- An implemented food insecurity protocol that enables food insecure people to use their facility in some way that can help lessen their food insecurity.

The people that had the information we were looking for held a high position occupationally at the school. These people were administrative faculty or volunteers who are responsible for running the greenhouse, education plans, and food insecurity protocols. A person who has a long standing career at the school we also considered worth interviewing. Regardless of the position one holds, we consider it important to avoid risky scenarios. The information required for our study is available to the public and thus we will not be violating any confidential information standards. No questions were specific to any person and thus we did not ask any personal questions. Instead our questions pertained to the college population as a whole. For our report we of course needed to reference who it is that we interviewed for the sake of scientific observation. In this case to keep the interviewees anonymous we gave a generic description of the position they held. As in section 4.3, any pictures or videos were stored in a password protected folder. Any photo not approved by the source to be used directly in this report or presentation was deleted upon release of our final report. Possible risks that might emerge from our interview could be a problem with an employer or privacy rights of the interviewee being violated. Given our non personal questions and the measures we have taken to keep interviewees anonymous and private, the risk of running into a problematic scenario is reasonably low.

3.3. Case Criteria, Identification, and Selection

We laid down criteria for selection of the cases based on the desired data type to collect for our study. Then we identified cases that can get the data we need. Next we used the created criteria to select which of the identified cases to include and which to exclude in our study.

This uses a Most-Similar Pathway case study, also known as the Method of Difference. The intention is to provide some comparisons between a treatment case and a control case, while controlling background features. In this, the causal mechanism are observed for their apparent impact of food insecurity on college campuses. This allows for the exploration and identification of unknown mechanisms or confirm a stipulated theory (Seawright, Gerri, 2008, Pg. 304).

A weakness that comes from this is related to the operation of the greenhouse, more specifically regarding patrons, education, systems, and what's grown. For instance, selecting a business for a case does not deal directly with colleges or college students necessarily. In this case, a business will operate somewhat differently than a college greenhouse, and have different patrons; customers as opposed to students/professors. As such the systems used and plants grown may be different, as plants for sale may be handled differently than plants for research, which will require and attract different patrons. Arguably it is worth looking at this even though the operation is not necessarily the same as the overall nature growing plants is the same, with the difference being the intention and types of plants.

3.3.1. Case Criteria

We created criteria to help us identify cases based on the 3 components mentioned in the introduction: optimization of greenhouses, education plans, and food insecurity protocols across communities. The criteria explains in a more detailed manner what we looked for in these 3 components so that we are able to use them to identify and help us best select cases in the following steps.

Table 6: Case Criteria Identification

	Does the organization have this? (Y/N)
A specifically designed greenhouse for optimization of their greenhouse's structure to benefit their plants for its purpose of use;	
An implemented education program on Greenhouse case and use;	
An implemented food insecurity protocol that enables food insecure people to use their facility in some way that can help lessen their food insecurity	

3.3.2. Case Identification

After we determined what information we needed, we then needed to put plans into place to get the information we required. Like many things, this involved analyzing how others have done what we are trying to recommend that QCC needs to do. Specifically for us, that was analyzing the collected data of operations and optimizations that other organizations and people have implemented across our 3 components.

Before we could perform interviews, observational studies, and document analyses, it was necessary that we identify and select the cases. We needed to find organizations that have greenhouses, education plans, and/or food insecurity protocols. The more components an organization has experience in the more optimal it would be, especially if they combine the components to work together. The best ways we have discovered to perform our research of identifying particular organizations with these attributes is through simple google search using keywords such as: Optimizations of greenhouses, Education plans, Food insecurity protocols, College, Business, Food pantry, outdoor education, sustainability and more. When performing search engine tasks with these words using Google, we came up with several links to different organizations that fell into at least one of our 3 components. From there we went to the websites for these organizations and identified if they fell into one of our 3 components or not. If they did, we found contact information to be able to conduct the rest of our methods of data collection & analyzation. It's important to note that even if they didn't fall into one of the 3 components but worked in an area that was similar, we still contacted them and used "Networking" to be able to ask them if they knew of any organization that did fall into one of our 3 components.

Upon finding a case that fits the criteria a key stakeholder was identified, as they were the people being interviewed. Identifying them involved reviewing greenhouse websites to determine who met an individual set of criteria.

Table 7: Determination of Key Stakeholders

Name of Potential Stakeholder:

Questions	**Does this apply to the individual? (Y/N)**
Involved in greenhouse administration?	
Has access to pertinent documents?	
Has experience working inside greenhouse?	
Able to answer interview questions in a timely manner?	
Has access to documents regarding college?	
Is there someone more fitting to speak with?	

Note: If all questions 1-4 and 5 (if applicable) are yes, and question 6 is no; this individual is the ideal person to interview

The person contacted was not necessarily the person who fit this criteria, but having this frame established allowed us to be directed to the proper person. Once the key stakeholder was determined, a date and time was determined for the interview.

3.3.3. Case Selection

We continued searching for cases until we had secured interviews with 3 organizations that fall under each component. We accepted organizations that do and don't overlap the components. What this means is one organization may have a greenhouse, an education plan, and address food insecurity, in that all three components overlap. In contrast, a different organization may only have a greenhouse with an education plan, or have a greenhouse and address food insecurity. A third scenario would be an organization having just a greenhouse, but no education

plan or food insecurity protocol. This opened up to the possibility that we won't exactly end up with 9 organizations at the end. The best scenario would be finding 3 organizations that each fall under all 3 of our components so there is the most data for us to work with.

We created a table to organize these organizations to show what components each of them have, making it easier to select the 3 cases that have the most components. The 4th organization is QCC, which is the impact case study. This was so that in the findings we compare QCC to the 3 other organizations we collect and analyze data from. QCC is also the focus for the specific recommendation that comes from the resulting conclusion. The 3 selections from this table and QCC are the organizations we use in the next 2 steps of our methodology, making it a total of 4 cases to collect and analyze data from.

3.4. Data Collection

Utilizing a case study to achieve the goal of this project generated a variety of data, all of which needed to be identified prior to ensuring it is collected and not missed as well as relevant. As there is a variety of data each had varying ways to be collected and analyzed.This section details what information was needed to be gathered from the cases, the process of contacting the cases, how documents, observational and interview data were collected according to protocols. Additionally it outlined the consent forms required to collect the aforementioned data.

3.4.1. Information Needed from the Cases

The required information consisted of background on the greenhouse (reason for its existence, who it's for, what went into creating it), the demographics of the greenhouse users including food insecurity statistics or insight, who runs and operates the greenhouse (such as staff or volunteers), operators' expertise and experience, how the greenhouse is run (physically and organizationally; structure, location, cost, plants grown, systems used, security measures, energy consumption, how logistics and statistics are collected/recorded/stored), what has and has not worked, what they've learned, what could improve their greenhouse, what sort of education component they have in place, what suggestions/insight they would have for other greenhouses. Utilizing the cases we have selected in step 1, we then moved into the contacting & interviewing step.

3.4.1.1. Consent Forms

The consent forms, located in Appendix C, were presented to the interviewees to record audio, and take photos of the greenhouse and surrounding area around the greenhouse. These outline what the files collected are used for, how they are handled, used, what happens to them after the completion of the project, and that consent for the interview, document, or observational data collection is not required. If the consent forms were not signed no photos or audio were obtained during and or appear in the project after the interview.

3.4.2. Contacting Cases

The contact & interview process consists of two phases. First, secure contact, and secondly, setup the interview . This was done after the key stakeholder was identified, and prior to the actual interview.

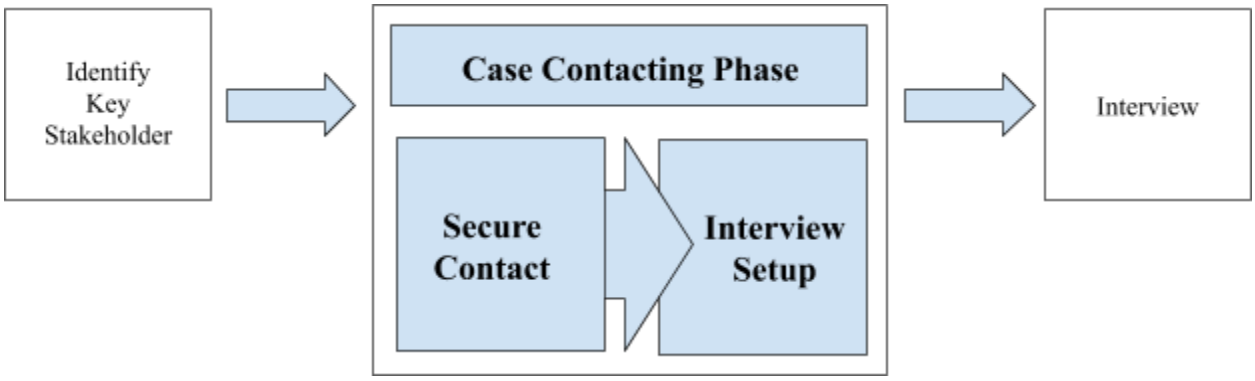

Figure 6. Shows the Steps Preceding and Following the Case Contacting Phase

Secure Contact

Here we contact an organization, inform them of our project, then ask if they would help us by being a part by agreeing to an interview. This allowed us to see if this organization could be used as a case or not because they had to agree to being part of the study. If they were able we proceeded to the interview setup.

Interview Setup

We set up a meeting either in person, over the phone/Skype, or through email. The interview questions were also sent, and historical/contemporary documents were requested. If the interview was not done in person we also requested photos and/or videos of the greenhouse and surrounding area.

3.4.3. Document Collection

Audio collected from the interviewees was done using an audio recording device. This is where the audio was stored, and only the team has access to it. It is secured inside a password protected folder on the device, and as well we put the files onto a computer for transcription. The files were also uploaded to a Google Drive folder, which only the team has access to. These files are not shared or accessible to anyone outside of the project team and are not used for anything other than the project. Upon completion of the project all of the files were deleted.

3.4.4. Observational Data Collection

Observational data includes photos and videos, which are necessary to inform decisions regarding the optimization of a greenhouse. These data specifically target 5 main components; the facility structure, the plants, the systems, the environment, and other areas of interest. Each of these components give insight into how already standing greenhouses work and where these workings are succeeding or failing. This data was collected using a DSLR camera for photos or a hand-cam recorder for videos. If a camera or camcorder were not available a cell phone was used

The structure components includes the actual greenhouse and materials it's made of, inside and outside. The types of plants relates to what plants are grown, how they look, and their layout. The systems include how the greenhouse operates; watering, lighting, temperature, and storage. The environment relates to the surrounding area of the greenhouse, but not the greenhouse itself, such as the geography for instance. Other areas of interest are a much broader

component, but includes anything that doesn't fit into the other four components such as fliers for example.

The observational data collection protocol, located in Appendix B, details the 5 observational components, mentioned in the previous paragraph. It gives greater detail as to what these components are and what aspects of those components that are collected. Furthermore it explains the reason why these components were selected and why they are important for achieving an optimized greenhouse.

Similar to the Document Collection process, any photo that was taken was put in a private Google Drive folder during the project, only accessible to the project team. All photos were deleted by the end of the project, aside from any that are necessary to be used in the report or presentation which has been approved for use from the specific case study. A photo would be considered necessary to showcase specific aspects that cannot be described with words adequately or is of specific interest, such as a unique setup or situation. Consent to take and use photographs is explained in the Photo Release Consent form, found in Appendix C.

3.4.5. Interviews with Key Stakeholders

A “Key Stakeholder” of a Greenhouse is someone that has an intimate understanding of the overall and specific operations of the greenhouse. This preferably includes history, logistics, and maintenance of the structure and plants. They are active in the greenhouse itself, to ensure they have a working understanding of the reality of procedures and what goes into making it function. They have access to documents that allow them to fully or reasonably answer questions, and do not have to go to someone else or more than one other higher level person for

answers. For instance, it would be sufficient if a question about finances could be answered generally, but a day to day break down of spending would be deferred to someone else.

The interviews followed a semi-structured format, to allow for a more in depth and natural discussion. An Interview Protocol with the questions that are asked is in Appendix A. The interview itself was conducted and recorded at each facility area. For all in-person interviews the audio was recorded, along with highlight notes for reference taken during the interview. Additionally during the physical interview photos were taken of the greenhouse and surrounding area.

An important method used to understand the facility procedures in other working greenhouses was to interview key stakeholders. These key stakeholders were people who can provide the most data about their facility. This individual would be higher up in the chain of command, having access to documents pertinent to various aspects of their greenhouse project such as financial records; the history, structure, and yield of the facility; as well as problems and changes made to the facility. The key stakeholder is able to directly contact others who may have useful input of interest. Furthermore, the key stakeholder is someone who has physically worked in the facility, or has at least spent time in the facility and knows what goes on in the greenhouse, as well as what it grows. This allows them to speak accurately about what is actually done in the facility, what it yields, and what the issues are regardless of size. A key stakeholder is able to give data, not just about the theory of what should be happening in the facility.

The questions asked are related to our goal statement thus, we ask specific questions about the plants they grow, the structure and operation of the facility, the history of the facility and the reasons for any pertinent changes that may have been made to the structure or operation

of the facility. Additionally questions are asked related to the financial details of the facility, how the facility and its produce affects the community, and what the facility education program (if any) looks like. All of these general themes and their associated specific questions can be found in the Interview Protocol, in Appendix A.

3.5. Data Analysis

This section details how the collected documents, observational data, and interviews are analyzed. As each set of data contains similar and related information, but is presented differently, each requires its own process for analysis. To adequately analyze the data qualitatively the following techniques have been implemented; careful interpretation of the data, triangulation of analytic techniques, and investigator triangulation.

Careful interpretation of the data comes from reviewing the available data, such documentation, interview transcripts, and observational data, and parsing relevant information. Following up on questions about available information and researching points of data further improve the interpretation. A wider and deeper understanding of the material allows for a more accurate analysis. Triangulation of analytic techniques entails reviewing data in multiple ways. Combining relevant information, removing irrelevant data, and grouping data across cases by specific formats improves the way data can be examined and compared (Teddlie, 2002, Pg. 233). Investigator triangulation is done by having multiple people review data, multiple times, and in different formats. This allows for the information to be examined multiple times, with multiple expectations, and goals set to ensure no information goes unnoticed.

3.5.1. Document Analysis

The original intention for each case study was to use a business analysis as a framework to allow for quantitative and qualitative comparisons to be done. Statistical and logistical data was compared between two cases as well as across all cases, which included cost, expenses, size, yield amount, and population, but is not limited to these categories. Any additional information being tracked was also noted.

This depth of analysis did not occur due to being unable to acquire documents from more than one case. The primary reason this occurred was because only one case was primarily in charge of their own historical and financial documents. This case had no access logistical data such as energy or water usage. The key stakeholders of the other three cases did not have access to these types of documents across the board. This seems to be due to the nature in which these facilities were constructed. The case that did have documents planned, fundraised, and built the facility themselves, where as the others were not done in this manner.

3.5.2. Observational Data Analysis

Analysis of observational data was done by reviewing photos for each component for insight into how the facility functions which may be overlooked by someone discussing it who is familiar with it. The data collected was reviewed and organized (Table 8) by case study then components. Data were given a file name, and the case it is related to, allowing it to be referenced and easily compared with other data. Subsequently the main component being focused on will be noted along with other components that are present. For data with multiple

components the main component can be changed to allow further examination. Once data was categorized by these aspects it was compared to data that has a similar main and subsequently component list.

Table 8: Observational Data Analysis Review Chart

Component	*Explanation*
Data Name:	
Case number:	
Main Component:	
Subsequent Component(s):	
Similar Data and Case:	
Similarities/Differences:	
Notes:	

3.5.3. Interview Transcript Analysis

Interview transcripts allowed us to analyze keywords, and links sections together. The goal of the data was to provide us with the grounds necessary to recommend effective strategies to the operators of the QCC greenhouse. Therefore, the analysis of the data was also especially geared toward that goal. To begin with, we created a categorization of the gathered data to provide a meaningful way to think about, analyze, and present our findings. We started with several broad categories, and then sub divided those into a number of more specific concepts. This method also allowed for an orderly cross comparison of the individual case studies, and renders the scrutiny of any particular aspect of the study an easy task.

After having categorized the data within each case study, the analysis methods previously mentioned were employed. Data was carefully reviewed through categorizing and organizing the data, then parsing out what was irrelevant to the components and themes. If other data that didn't fit into these section was present, and was relevant, a new section was created for it to ensure no useful information was missed. Afterwards analytical triangulation allowed us to later compare this information across the multiple cases. This was done by creating a table based on the components and themes, and listing the specific data for each case in the table. This finalized table is located in Appendix F.

Investigator triangulation was done by having multiple investigators review the data in the categorized data table. This list was manipulated numerous times to compare cases in a different way, such as listing what one case did without any of the other cases, and grouping the most similar cases together. While these tables were being manipulated, multiple investigators were present and reviewing the data.

This was interesting since the case studies included a number of different settings, so information that may seem to be contradictory were, in fact, found to be entirely accurate, and only differs because it represents a difference in the circumstances of the interviewed facilities. This in itself proved to be very interesting, and helped to portray the strengths and weaknesses of the different possible ways of running the QCC greenhouse. Finally, a summary was made of the takeaways - the gleanings - from the information in the case studies, and an explanation was made of how these takeaways impact the stated goal of the project.

3.6. Summary

This chapter reviewed the procedures that was followed for the case studies of this project, using a Most-Similar Pathway case study methodology. Outlined in this chapter are the case study methodology, the case criteria, identification, and selection. The data necessary to complete this project was collected across three components; documents, observational data, and interviews. Additionally once this data as collected it was analyzed following the procedures laid out in this section.

The case studies of the greenhouses are selected for their link to food insecurity, education, and optimization. The data on their greenhouses were gathered through semi-structured interviews, which were then compared across the studies to help determine how to achieve an optimized greenhouse with an education plan. Along with this document there is an interview protocol and an observational data collection protocol.

The interview protocol details the questions and topics that were used during the interviews for gathering the information that has been determined to be the most important, but also allowing the interviewer to get a more in depth knowledge of topics or explore topics that hadn't been considered. Along with the interview data, historical, statistical, and media data were obtained for thorough examination of the case studies. The Observational Data collection Protocol outlines what the data criteria was, what data was collected, and why it is necessary for the project.

The next section summarizes the findings of these case studies and data, excluding specific information of where these studies were done aside from Quinsigamond Community College's greenhouse as it has already been identified in the background chapter. This is done for the protection of the individuals and establishments contacted and to create a non-biased recommendation in the discussion chapter.

4. Chapter 4: Findings

4.1. Introduction

The following sections of this chapter detail the findings from our four case studies of colleges that met the case criteria detailed in the previous chapter. The names of the colleges have been changed to a descriptor to protect the anonymity of the interviewees, with the exception of Quinsigamond Community College which will be labeled as Case Study 1 (QCC). The others are labeled Case Study 2, Case Study 3, and Case Study 4. Each college met at least two of the three criteria of having a greenhouse, education plan, and a food insecurity protocol in place. To analyze the data collected, we utilized the case study method called Method of Difference, as well as "Triangulation" which are both detailed in the Methodology Chapter. The individual case studies utilize interview data, observational data, and statistical documentation when available. These allow for improved depth and breadth for understanding the cases, and enhances the completeness of findings (Evers, van Staa, 2012). Following the individual case studies, a cross case analysis is done. This summarizes what was found in the cases and reports the findings across all the cases which are the same, different, or were expected but not present in any.

Table 9: Theme and Component Explanation.

Components and Themes	Definition
1. Optimization	
Structure	Physical makeup of the facility.
Materials	Items used at facility, not imperative to structure.
Automation	Systems that are automated in whole or part.
Plants	What is grown in the facility.
Environment	Area the facility is located in.
Sustainability	Operations related directly to sustainability.
Organization	Practices or objects used to keep the facility and equipment organized.
Records	Financial, logistic, statistic, or informatination logs used at the facility.
Safety	Practices or systems that directly relate to safety.
2. Education	
Training Staff	Practices preparing patrons to function in the facility.
Experiments	Types of experiments done at the facility.
Community Awareness	Practices that involve or make the community aware of the facility.
3. Food Insecurity	
	Practices, operations, or protocols that directly relate to food insecurity.

4.2. Case Study #1

4.2.1. Introduction

Background

The facility started as an idea in 2004 of one of the students, Mary Bailey, which was to feed the hungry students on the QCC campus. It took ten years for the idea to come to fruition. The original idea was to start a garden, but due to natural arsenic in the soil, the idea was changed to be a greenhouse. Since space is limited on the campus and the facilities department was hesitant of the project, the requirement was that the greenhouse be fitted inside a bus hub that was already on campus. To do so, engineering students from the school had to repurpose it. They removed all the windows and replaced them but had to keep the top of the hub, limiting the available sunlight. The hub was also located in very close proximity to one of the buildings, meaning only two sides of the greenhouse would get sunlight during the day.

Along with physical restrictions, Phi Theta Kappa also had to raise their own money for the project. They did so through fundraisers and donations totalling $16,000. Despite all the issues that had to be overcome, the greenhouse was built and became operational in July 2017 with the help of countless PTK members, alumni, volunteers, and advisor.

Demographics

The demographics of volunteers who work in the greenhouse is primarily members and alumni of PTK, and there are also members of the college facilities that assist with maintenance.

The Facilities Manager of the college helps with the greenhouse on occasion for various tasks, and the college's maintenance workers often assist in fixing things the students aren't equipped to handle. As members leave the college and new students join PTK, the workers change. At the college there are over 7,200 students, with a majority being part-time (65%) and under 24 (60%). There is also a wide variety of majors; Business, Health Professions, Liberal Arts, Homeland Security/Law Enforcement, Public Administration, Engineering, and Education to name the most prominent in order. Due to these diverse cultures and majors the patrons of the greenhouse has a very broad skill set, and bring a lot of different perspectives (NCES, 2019).

The demographics of those who receive food from the greenhouse are primarily QCC students. The college has high racial diversity, with 54% being white, 20% being Hispanic/Latino, 13% being African American, 5% being Asian, and 8% being either two or more races or unknown (NCES, 2019).

4.2.2. Optimization

Structure

The facility was built using a repurposed city bus hub, making it a small, single room structure. It has special glass for the windows to optimize sunlight, and is located next to one of the college buildings. The glass cost QCC about 85% of their initial building budget alone.

Figure 7: QCC Greenhouse, Showing Outdoor Plants and Surrounding Area

Materials

Has a cooling system with fans, vents and temperature control, automatic lights, and a camera for security and live feed. There are multi-level, metal shelves, and a system of rails along the ceiling to allow for hanging plants. A drip-watering system exists but is not set up, which would potentially allow for automatic watering.

Figure 8: The Inside of the QCC Greenhouse, from One End to the Other, Standing by the Entrance

Automation

Automation is not completely utilized in the greenhouse, although there are systems that are set up and/or partially used such as the drip-watering system. The heating system is the only one that is fully utilized. The watering system is in place, but the staff there stated that it is not

being used because it's not worth doing and it's too difficult to get working properly. There is a website that monitors the temperature and humidity inside the greenhouse, which is helpful for tracking, but it does not turn on either the heating or cooling systems that are installed. Those are all handled manually. There is also no room to include an automatic window system since none of the windows are able to open.

Plants

Thousands of dollars worth of plants, herbs, and vegetables have been grown there, including cucumbers, eggplants, peppers, tomatoes, lemons, and even pineapples, among many others. Plants are grown both in and outside of the facility in certain seasons when plants are able to survive outside. As the main goal of the greenhouse is to address food insecurity fruits, vegetables, and herbs are the main plants being grown. The seeds they grow come exclusively from Johnny Select Seeds, located in Maine, which are all non-GMO, pre-pollinated fruits, vegetables, flowers, and herbs. Once their crops are grown they are logged, weighed, and put into the PTK Food Pantry for students to take as needed.

The plants are generally healthy both inside and outside, but there is a bigger difference between the outside plants. Some of the plants had damage to their leaves, likely eaten by bugs. Nothing seemed to have been from animals or people. The largest difference came from the tomato plants. The larger plants didn't seem to have any damage to them, and they also seemed healthy.

The plants inside all seemed to be healthy and had no visible damage from pests or disease. Something the staff had recently learned regarding keeping plants healthy was that

individuals who smoke cigarettes needed to wash their hands before they handle the plants. The greenhouse manager noted that "volunteers have to wash their hands if they smoke or they can transfer disease to the plants, and it's noticeable. Some plants had white spots on their leaves, and it was due to contact with the smoker."

In 2019 a food log was created which tracks what has been harvested. They weigh everything that is grown, even things that can't be consumed or used. They don't measure what gets thrown away in the log.

Environment

This greenhouse is located on the ground, as previously mentioned, as well as in close proximity to a building and staff parking lot. Due to being so close to the building, some of the sun is blocked by the building which makes the use of artificial lighting necessary. The greenhouse has been subject to security issues such as outside plants going missing or eaten, as well as things having gone missing from inside. The missing items from inside were earlier on in the project, and having added a camera has stopped the problem completely. Being on the ground, it has also had its share of pests, which may come in through the vent or when the door is opened.

Sustainability

A worm farm is used to make up for the fact there is no plant matter composting available, which is due to administration orders. Plants that can't be eaten are put into a container filled with dirt and worms, which is made to collect the liquid waste from the worms. This is

called worm tea, and it has been used in the soil for some of the plants being grown. Using this on the plants has caused a noticeable difference in growth compared to the same type of plants that don't use it.

Figures 9 and 10: (Left) Worm Farm Container, Filled with Newspaper. Objects Alongside of Container are Worm Castings (Right) A Clump of Dirt Containing Numerous Worms

Organization

Inside and outside the greenhouse, plants and materials are put into an organized fashion to reduce clutter and improve the flow of the work. On the inside, there are shelves that pots are placed in, and there is a strip fastened to the wall where tools can be hung from. Also on the inside of the door there is container where binders can be placed to keep track of logs and other

documents. Along the outside there are shelves where potted plants can be placed and on the side there are tomato plants which are grouped together as they are too big to fit inside.

Records

PTK raises its money through fundraising and charitable donations generally. One of the things the chapter members are used to and good at is fundraising, which is their main source of income for everything needed to run the entire chapter. The rest of the cost to build the greenhouse was raised entirely by the chapter during events they regularly hold. With this the staff of the greenhouse learned how to budget accordingly with limited funds, through buying supplies, necessary upgrades, and plants to be grown.

PTK applied for and received a grant for $16,000 dollars to be used for the entire greenhouse; of that amount they used $14.5 thousand on the windows alone. The cost for labor, equipment, furnishings, and other supplies would very quickly take care of the remaining grant money. PTK had a plant sale fundraising event, selling plants and herbs grown in the greenhouse, and all the proceeds went to the greenhouse for supplies. The college is not making profit off anything sold from the greenhouse, nor does PTK as they are a non-profit organization. All the money raised through fundraising and donations are used for supplies, food, travel, and charitable donations.

Safety

The facility has a key-locked door as their main source of security. The key is logged out to keep track of who has it to ensure no unauthorized people are able to get into the facility when they shouldn't be there. Additionally there is a camera system inside the facility, which allows

the staff to monitor the inside as well. There is also a sign that says "Smile, you're on camera" which the greenhouse manager believes helps. The camera also occasionally generates a live YouTube stream, as mentioned previously.

4.2.3. Types of Education

Training staff

Staff and volunteers are trained on the current procedures and processes necessary to take care of the plants and greenhouse. The current Greenhouse Manager and new staff are trained by the previous Greenhouse Manager, prior to the previous manager stepping down from their position. Anyone that joins the staff or volunteers is subsequently trained be the current manager. Most of the previous learning had been done through research, experienced staff members, and YouTube videos. As with anything else they've learned things along the way from trial and error.

The training includes watering, drying, weeding, transferring plants, cleaning, and general maintenance of the greenhouse, surrounding area, and plants. While there isn't an education program specifically targeting individuals, anyone that volunteers in the greenhouse learns a myriad of skills, the aforementioned as well as soft skills like communication, team building, and following directions.

The greenhouse manager noted that it was "a new greenhouse, and everyone is still learning." They are still finding out what works, and doesn't work, and even do experiments and track the growth of plants. Even failures that occur while working in the greenhouse offer opportunities to learn about things like the relationship between certain plants and herbs, insects and the plants, the temperature and humidity needed, lighting, along with general operational

practices, but also how to handle and research unexpected crisis. When plants get sick or there is an outbreak in the greenhouse, the staff must determine what's happening and how to fix it. To determine how to remedy these issues, the staff generally does their own research online, using search engines and horticulture websites. If the problem can't be handled by the staff's research they will reach out to professors from the Biology department for assistance.

Experiments

The facility is not research oriented and consequently studies haven't been conducted specifically. The primary experiment they have done so far was determining the general benefits of using the worm tea on plants. As noted in the plants section, the largest difference came from the tomato plants. One group had been given the worm tea (explained in the sustainability section), and another group had not been given the tea. The group that had been given tea was growing faster than the group without it. The tomato plant experiment had noticeable results between the growth of the worm tea fed group and the non-fed group. The current president of PTK noted she intends to continue to do experiments to help learn as much to pass onto the new group working in the greenhouse.

During the interview the current president of PTK had mentioned the idea of doing a sound experiment, to see what sort of music or sounds make plants grow better. She mentioned the limitation of separating them so the sounds wouldn't interfere. In their current greenhouse they wouldn't be able to do this, but the experiment itself was not likely to be conducted in this current greenhouse anyways. This was an example of some ideas they've had for the experiments, which were constantly being thought of.

Community awareness

There is currently no specific education program or plan in place in the greenhouse to generate community awareness. In the past there have been events with children to plant seeds, but nothing has been continuously on going. The only educational component is tied directly into food insecurity. Occasionally student-mentees from the PTK mentoring will have the opportunity to visit and learn about the facility.

Additionally the facility has its own logo, which is posted visible on the door of the structure. There are also fliers and shirts used for advertising the greenhouse. There have also been news articles and videos done about the facility.

4.2.4. Food Insecurity

The main purpose of the greenhouse on the QCC campus is to address food insecurity. All the food that is grown in the facility is put into the PTK run Food Pantry, where students, teachers, and facility staff are able to take out a certain amount of food. As mentioned before there is information available for food assistance program in the food pantry for people who qualify.

There are food resource programs, specifically SNAP and WIC, that have information available in the PTK Food Pantry. According to research done on the campus, 49% of students are food insecure, making it necessary that these programs be available. Occasionally individuals from the SNAP and WIC offices will be present in the food pantry to assist people in filling out the necessary forms to apply for the programs.

Currently there are efforts to partner with one of the local Mobile Farmers Markets. These have been shown to be effective at increasing consumption of fruits and vegetables to areas of food insecurity (The Board of Regents, 2015). Individuals can also use SNAP benefits for fresh produce at these mobile markets, and some amount can be repaid to the individual essentially making them free for the buyer.

4.3. Case Study #2

4.3.1. Introduction

Background

The greenhouse was built around 1996, with the primary function of allowing biology and biotech students an area to perform research and experiments. It has two rooms specifically for research, as well as a room in the hallway leading to the structure that research is often conducted in.

Not all of the research is focused around growing plants. Bumble bees have been grown by the biology department, and crayfish were also grown. When there is available space, the greenhouse is available to any student outside of the 2 departments. A youth group and a greenhouse club are frequently active in the greenhouse. The greenhouse club has made the facility more popular because of their activity.

The greenhouse is run as a democracy, with the Greenhouse Manager directing students, helping others, and working with advisors. The Biology professors set out the requirements of the greenhouse, along with the manager's bosses and supervisors, and the Department Head,

which the Manager facilitates. To meet these requirements the Manager directs work-study students that are working in the greenhouse, along with volunteers - although there are currently none. The non-Biology department students, such as those in the youth group or greenhouse club, have no say in what happens.

The rules are set by the Supervisors and the Manager, who then deal directly with the professors. This system has been working well as the initiative given to the Manager is not abused, and communication is kept direct. WPI Administration are not bothered with unimportant things, which means some areas of the chain of command may not know the specifics of running the greenhouse.

Demographics

During the school year the number of people who use the facility on a weekly basis fluctuates around 45 to 50 people. Most of the patrons are students from the biology department, then the rest of students on the campus such as other programs and clubs. Non-students, such as the youth group, make up the other main portion of patrons. In addition professors also visit and use the greenhouse.

Changes made to the Facility

The main change to the greenhouse has been how popular it has become due to the greenhouse club. There haven't been any physical changes made to systems or the structure. Although there are some leaks and sensors that don't work the way they should, which the manager hoped to have fixed.

Suggestions Already Made

The school has already had suggestions on how to address food insecurity in some fashion. Aside from growing food for consumption, this included creating a Food Insecurity Task Force. The greenhouse manager said he was interested in trying new things, but did not mention if this was going to be something they were going to do on either account.

4.3.2. Optimization

Structure

The plants are situated on tables that line the walls of the square rooms, leaving the center available for another stand. The tables are high enough that a normal trash barrel can fit under them. There is baseboard heating under tables that are used to house plants. Each room has four relatively-small windows near the top that open outwards.There are two large fans in a 5th and 6th window. There are hanging fans and aspirators (which is like a fan) that are mounted in beams near the outside of the rooms. They can be moved by hanging them from different holes in the beam.

The greenhouse structure itself is completely removable, and was built to complete some sort of requirements for the biology department. The structure has multiple angles which makes it difficult to shade and regulate the temperature. This is an issue in the summer since there is not automatic cooling system in place, but it is not a problem in the winter. During the winter the issue is that there isn't enough sun. The greenhouse has special glass in the windows to optimize heat retention.

Figure 11: One Room of the Case 2 Greenhouse Including Plant Variety, Materials, and Structure

Materials

The tables were all the same height, made from metal, and have a grated top. Some of the tables also have trays or tubs on them, which plants are placed in to collect water and dirt from falling through onto the floor. This makes for a cleaner area, and makes moving plants easier.

There is a heating system in place, but not an automated cooling system. To cool the greenhouse, fans are used and windows are manually opened. There is a thermostat which has a max temperature around 110 Fahrenheit, and a thermometer in the main section of the

greenhouse. The facility has set of a Watson brand hanging-fans that assists in circulating the air in the rooms, and there are ventilation fans a few windows to circulate air to the outside. Usings a set temperature for the facility, once it is reached the windows are opened manually to lower the temperature. There is an alarm in the greenhouse which is used regarding the temperature. This alarm is triggered if the temperature goes out of the range that has been set (around 110 F at the most).

There are artificial lights on timers, but they're not used on a regular basis as to conserve energy. There is a room located outside of the greenhouse, inside the building, which does have artificial lighting and has no windows. This room is used for research, and occasionally cleaning plants if necessary.

A watering system is set up throughout the greenhouse, with hoses in each room to allow for manual watering. With that there is an automated watering system set up, but it was not active.

Automation

Nothing in the facility is completely automated, but there are automated systems in place such as the lights, watering system, cooling and heating systems, and the windows. The windows had to be manually opened to regulate and lower the temperature of the greenhouse. The lights were set up to be automated but isn't used unless an experiment requires them, and to conserve energy. An automated watering system is also set up, but not utilized.

Plants

The plants grown are for research and experiments, and not food. There is a wide range of plants that are grown, 90% of them being perennials by the college students. All the plants being grown inside appeared healthy; no signs of mold or pests. Members of the greenhouse club or the youth group may grow food, but otherwise the only food grown is for research and is not consumable. There is a wide range of plants being grown, a few being Vicks Plant, peruvian lily, Paper Spine Cactus, Gollum, echeveria, pineapple, and lemon.

The greenhouse club occasionally sells plants that have been grown in the greenhouse to benefit the club, and 10% of the profits going to the biology department. This is the only source of revenue for the greenhouse aside from the college, and the only plants that are being sold.

Environment

The greenhouse facility is located on part of the roof of the college. It is connected directly to the building, accessible only through a lockable door from the hallway. There is an area outside of the structure on the rest of the roof that is open space, only accessible through the greenhouse.

Sustainability

The only sustainability aspect of the greenhouse was found in an experiment where a plant was reusing water. The water traveled across a patch of moss and other plants, into a pool, where it was then pumped out of the pool back to the top of the structure the plant is situated on.

This wasn't an experiment to reduce energy costs, it was academically related. There are no other sustainability practices occurring in the greenhouse.

Figure 12: Sustainability Experiment

Organization

To keep the greenhouse organized one of the four sections of the is dedicated to storage; there's a sink along with shelves for pots and containers. Due to the setup of the rooms the facility is very organized, and there is minimal clutter if any. There aren't any procedures in place specifically regarding organizing materials.

Records

There aren't records for finances or energy consumption being kept by the Greenhouse Manager. The main records being kept is an inventory for the classes that use the greenhouse. Aside from inventory, a record for the key holder and for the work study students. Since the plants aren't grown for consumption by the college there aren't any records available for this. The Key Holder record tracks who has the key to the greenhouse, which the person signs off when they return the key. The Work Study record requires students to log into a system and record what they have done during their shift.

Safety

For security there is a key that locks the entrance of the greenhouse, with a log of who has the key as previously mentioned. The person with the key is responsible for signing off when they return it, and if they lose it they must pay to have it replaced, as the locks may also need to be replaced. There are no cameras inside the greenhouse itself, but if anything there are some outside the area it is located. In addition there is a warning sign indicating the floor is slippery when wet.

4.3.3. Types of Education

Training Staff

When a new person is hired for a work study, they are trained by the Greenhouse Manager. The work study students primarily work on watering and taking care of plants in a simple manner, based on what they've learned in the training. There is also a seedling guide for

troubleshooting common problems is posted in the main room, which lists symptoms, possible problems, and suggest solutions.

Experiments

The main purpose of the facility is for experiments and research for students and departments. There is a variety of experiments being conducted by the Biology and Biotech departments even during the summer. Some previous experiments have included the usage of artificial lighting to extend growing seasons, and growing insects such as bees.

Community Awareness

Other than the education and research done by the Biology and Biotech departments, there are programs and clubs for the community to learn from. There is a program called Plant Parenthood that begins at the start of each semester which gives club members hands-on experience propagating cuttings, starting new plants, watering, and pest control. Additionally the campus Greenhouse Club allows access to the greenhouse, and promotes being active with and learning how to grow and take care of plants.

There is an outside group that uses available space of the greenhouse, called the YouthGROW, which is a program initiated by the Regional Environmental Council (REC) of Worcester. The REC is a grassroots program that promotes fair and equal access to healthy, sustainable and affordable food for all, and the YouthGROW program is "an urban agriculture-focused youth development and employment program for low-income teens." This

program allows members to gain leadership and job skills, while participating in workshops, internships, and community service (Brimmage, 2019).

4.3.4. Food Insecurity

According to the interview, at this college 24.3% of students identify as being food insecure. The main concerns that the students have are having enough time to balance their academics and eating, having the funds to cover food and other expenses, and having access to food. To address these concerns, students may skip and skimp on meals, or ration it to ensure they don't run out of food. A factor that contributes to this coping mechanism is likely the lack of nutrition education.

There is no food insecurity plan in place with the greenhouse, as there is no food production done. The greenhouse manager thinks it would be a good idea, is open to new ideas, and had mentioned a previous suggestion he had received to start a Food Security Task Force. The closest thing to food that is grown is done by YouthGROW, but they only grow and sell seedlings when there is available space. Otherwise the only other food that is grown by patrons of the greenhouse are for research as opposed to consumption.

4.4. Case Study #3

4.4.1. Introduction

Background

This greenhouse was originally built in the 1970's, but was then rebuilt again sometime before 2000. The greenhouse manager wasn't certain on the date, as the reconstruction occurred prior to her starting. The primary purpose of the greenhouse is for research and education, and it is used once per semester for experiments in the college's Intro to Biology class. Other projects have since taken precedence over the greenhouse, as in recent years the greenhouse was reduced from four bays down to two, so that pipes could be run for a new science lab.

Demographics

In general at the college, the student population is rather diverse. With a diversity score of eighty one out of 100, the college has almost a fifty - fifty split between male and female students, about an average level of racial and ethnic diversity, and an age range of from nearly eighteen to twenty two, with approximately 96% of students being between the ages of eighteen and twenty one.

The primary patrons of the greenhouse are students of the Biology department, and from outside the college, there are often members of YouthGROW. The students participate in research, and when there is space available in the greenhouse the members of YouthGROW grow plants. Additionally, there are some agricultural related classes at the college, and those

students occasionally spend time in the greenhouse, or other departments such as Physics, which will conduct experiments.

4.4.2. Optimization

Structure

The Greenhouse is on the roof of one of the campus buildings, and is composed of two bays, although it previously had four bays, the number of bays having been reduced in order to make room for the science lab mentioned in the case study background. The rooms are set up with tables forming isles to allow for access to the most area on the tables. There are drains in the floor to remove water that's been spilled, and the windows are made out of special glass to optimize heat retention.

Figures 13 and 14: The Left and Right Side of the First Room of the Case 3 Greenhouse

Materials

The facility has various rows of grated tables, at a single fixed-level but could potentially have a second level. The reason there is only one level is to ensure all plants get adequate

sunlight, as there is limited use of artificial lighting. Plants are primarily watered manually with hoses and watering cans, although there is an automated watering system in place. There are multiple washing sinks, two located inside and one outside the greenhouse. The primary issue with the sink outside is there isn't a dirt bin, which leads to dirt building up in the pipes.

There are tubs which the potted plants are placed inside of, on top of the tables which reduce messes on the floor and make it easier to move multiple plants at once. The soil used has peat moss in it. To accommodate for the single fixed-level tables chairs are available to make working on plants more comfortable.

There is also a swamp-cooler system in place, but not utilized. This is a system of evaporative cooling where hot, dry air is passed across water, which causes it to evaporate and humidify the area, reducing the temperature. Another way to reduce the temperature plants are exposed to are with shade cloth. These had been used in the past, but are not used consistently - although there was one being used for an experiment, which can be seen in Figure 13.

Inside the greenhouse, as opposed to the hallway, electronic controls are susceptible to the heat in the greenhouse, especially during the summer. Due to this, two things that need to be monitored in the greenhouse are the electronic controls and the plants, specifically if the facility is at the right temperature. This facility has systems to monitor the temperature, but there aren't any alarms specifically to alert staff if the temperature gets too high.

Automation

The greenhouse has a heating and cooling system, along with multiple thermometers to track the temperature, as well as automated windows and fans. There is an automatic watering

system is in place but is not utilized, as the Manager believes manual watering is important for connecting patrons with the plants. Manual watering can also be an advantage since the necessity for hand watering brings people into direct contact with the plants on a regular basis, allowing them to watch the plants grow, and providing them with more experience. The manager of the greenhouse thinks that automated watering could prevent human error, but would need to be monitored in case of failure of the system for any reason. An automated system would also add expense to the greenhouse project, while cutting down on student interaction with the plants.

Plants

The plants grown in the facility are connected to experiments mainly, and aren't used as food. In the summer there's very little activity, and only a handful of plants were actually being grown during the investigation. The plants that were present were for research. Neither harmful insects, nor fungus have been a problem for the greenhouse, and plants weren't sprayed preemptively for these issues.

When food is grown in the facility it is by YouthGROW when space is available. The food grown isn't distributed to students, it belongs to YouthGROW. There are also no records to track what sort of plants are grown, or what amount, as this is handled by the classes for the experiment, and not by the manager..

Environment

The structure is located on the roof of a building connecting two science building. The facility is connected to the building, and there is a hallway with access to a class room, another

section of the roof, the area around the greenhouse, and a maintenance hallway. This hallway is where supplies are kept.and one of the sinks is located, along with the automation-systems controls. Due to the location above ground level, this likely contributes to a lack of insect infestation. This particular greenhouse has not had a big issue with that so far, and the plants are never sprayed in an effort to preemptively prevent harmful insects from getting into the plants, but they have had to spray for insects that managed to get into the greenhouse before. Insects can get in by means of someone walking into the greenhouse with an insect somewhere on their clothes, or by bringing plants from outside of the greenhouse into the greenhouse.

The facility is practically not visible from the ground level, making it extremely unnoticeable. From the main entrance to the building there is little more visible than the top of the structure, and it blends in with the pipe chase behind it. From the otherside of the building it is completely obstructed. Inside the classroom, which is connected to the hallway, there is a set of stairs and a lift leading to the hallway. This is the primary source of access to the facility.

Figure 15: The Green Box is Bordering the Only Visible Area of the Greenhouse from Outside of the College

Sustainability

There is no sustainable or renewable resources being utilized in this greenhouse. It seems the reason for this is due to the costs being covered by the college, and it not being a necessity. The energy consumption of the greenhouse doesn't need to be supplemented as the manager hasn't found the need for these to be added.

Organization

The storage space for the greenhouse is located in the hallway the greenhouse is connected to. There is a large set of shelves where the pots for plants and other supplies are

stored. The soil for the plants is also stored in the hallway, but there didn't seem to be a specific place for it, as it was in a corner away from other materials. Above the sink in the hallway is a drying rack where containers that have been cleaned can hang to dry. The greenhouse was clean and in order during the investigation.

Figure 16: The Hallway Outside of the Greenhouse, Showing the Sink, and Shelves for Supplies

Records

The main records that exist are regarding the key holder to the facility. The manager noted the facility was originally funded by a grant from the National Science Foundation (NSF).

Otherwise there were no records available for the greenhouse, as everything was handled by the college.

Safety

The main safety precaution directly related to the greenhouse is a locking door to the greenhouse, and the logging the key holder. Due to where the greenhouse is located there are other doors that have to be passed through to get to the greenhouse, and many of them were locked. Since the greenhouse is out of the way it is not likely to need more security than a key for the door, although the supplies in the hallway could be stolen if someone were able to get into the vicinity. There are no alarms or cameras in the greenhouse.

In the past some grow lights had been stolen when there was construction going on in the area. Since then the remaining lights are stored away and only taken out when necessary.

4.4.3. Types of Education

Training Staff

The main training done is by the YouthGROW for their volunteers, as the students who use the greenhouse have directions for their experiments. The manager had previous knowledge of how to garden and operate a greenhouse, and noted the main thing they learned was how to manage people. Since there are no volunteers or other staff for the greenhouse there isn't any specific training documents in place, since all of the work done to maintain the facility is done by the manager and another department head. If a staff member was hired they would have to already have past greenhouse experience and not require training. Students on the other hand

would receive training from their professor and would be specifically tailored to their own projects.

Experiments

The main focus of the greenhouse is for research and experiments, which are conducted by students of the Biology department. Occasionally departments other than Biology conduct research in the greenhouse, such as the Physics department. At the time of the investigation there were experiments going on, but it was a very small number, and generally experiments occur the most during the school semesters.

Community Awareness

The main source of community awareness is through the YouthGROW program, which uses the greenhouse when there is space available. Since the greenhouse doesn't grow food for students, and it's primary purpose is experiments, there are no fliers or advertisements to generate awareness.

4.4.4. Food Insecurity

In the past food insecurity has been dealt with through the greenhouse, with food being grown then distributed to the needy, but the practice has dwindled and no longer occurs. The manager was not aware of why the practice ceased, nor of any food pantry on campus, however, leftover food from the college has been distributed to people off campus, but not necessarily to students.

4.5. Case Study #4

4.5.1. Introduction

Background

The college of this facility had purchased a plot of land, which was occupied by the remains of a burnt down house. Initially the plot was going to be used for parking, but eventually made into a garden. Donations from the college facilities helped to start the garden on approximately one quarter acres of land. The city agreed to connect the water system to the lot. The original intent of the garden was to provide agricultural education for students of all ages. As time progressed, the garden, with effort from its planters evolved into more than was at first anticipated. The main purpose for the garden was for educational purposes in the spring and fall, and now address food insecurity issues on campus.

Demographics

The patrons of the garden are mainly students being educated on agriculture. Elderly folks who live close to the campus also greatly benefit from the garden and the garden benefits from them. Many of them come from a farmlike culture such as Albanian, and find it satisfying to harvest fresh produce in the familiar way of their native culture. As there are few farm produce markets within a reasonable distance from their home, the elderly find it very helpful to be able to harvest from the garden and get physical activity. Some of them grow their own plants

in separate lobbies then contribute them to the garden during the growing season along-side the other patrons.

The garden is run by a handful of staff. There is a part time garden project manager who hopes to manage full time eventually. Students volunteer for a practicum and help as garden assistants. Pharmaceutical students volunteer at the garden as well as students who are part of Girls inc, Students from the area's public schools, and the resident assistants from the college. Other classes voluntarily contribute to the garden while simultaneously being educated.

Garden Vs Greenhouse

The advantage of having a greenhouse as opposed to a garden is that you can control things that you cannot control in a garden. You can control droughts, vandalism, poaching, animals, pesticides, and the weather in a greenhouse. You can also grow plants year round in a greenhouse whereas in a garden you cannot. A garden on the other hand has the potential to facilitate a lot more people during a class depending on how much area the garden covers. Typically a garden is bigger than a greenhouse and although a greenhouse has the potential to hold many plants especially relative to its capacity for space, a garden will potentially be able to hold more plants just because of its sheer size.

4.5.2. Optimization

Structure

This facility is a garden, and as such has limited structural components. There are two sets of fences in the front and rear of the plot of land. The other two sides are made up of trees

and plants completing the enclosure. There is a cement walkway from the front, leading to a patio area and shed located near the rear. Behind the shed is another cement plot where a hoop house is located. The hoop house is not completed or set up. There is a composting area, which is sectioned into three parts for various stages of progress.

The facility has taken strives to ensure the area is compliant with the Americans with Disabilities Act (ADA) Standards.

Figure 17: Case 4 Garden, Including Area in Front

Materials

The facility uses general garden supplies, such as wheelbarrows, rakes, hoses, and ergonomic tools. The plants are all hand watered, as there is no automatic watering system. There are also various types of tables and shelves on which to work and organize plants.

Automation

Since this is a garden, and a very hands on program nothing is automated at this facility. This is because heating and cooling systems are not necessary, and a watering system wouldn't be worth setting up. This also gives the patrons of the garden hands on experience watering manually, and gets them closer to the plants more often.

Plants

The garden grows things such as tomatoes, okra, asparagus, purple basil, purple beans, green beans, and as many varieties of food for all different types of cultures. Along one side of the parameter are various types of berries and flowers, with flowers in the front as well. Originally the garden didn't focus on food insecurity, but after changing to grow more food there has been much more growth.

Environment

This garden is located outside, across the street from the college, and next to the middle school of the students that work in the garden. In the rear of the facility there is a basketball court. Since it is outside there is natural pest control and pollination, and plants are watered from the rain. The main issue with this is that there is little security, but that hasn't been an issue.

Sustainability

There is an area specifically set up for composting plant matter, as well as multiple compost bins stored behind the storage shed. Attached to the storage shed is a rain water drain

along the top, which collects the water and stores it in a large bin. As the garden has all age ranges of patrons involved in the garden and education programs there have also been classes where students recycle used materials. During the investigation there was a device that was made up of used water bottles, for watering plants. This is one example of the sustainability initiatives that the garden undertakes.

Organization

Near the back of the garden there is a shed where all of the supplies and tools are kept. It is large enough to fit a large number of garden tools like rakes and shovels, a large trash bin, and various other equipment for tending to plants and soil.

The garden itself also appears to be laid out in an organized fashion. There is a cement pathway leading from the front to the back, where the storage shed is, with a patio area in front where people can meet and sit down. Behind the shed is a cement plot where the hoop house is situated, and to the left of the pathway is where all the raised plant beds are. This makes access to the plants and storage very convenient, especially since there is adequate room between all the plant beds for movement.

Figure 18: Unfinished Hoop House, Located Behind Storage Shed

4.5.3. Types of Education

Training Staff

Training for this facility is done from outside groups and extracurricular classes. The Teaching Garden is an example of a one credit course that is offered by the college, which allows for students of any age to participate. The college also waives the course fee for students over 60 years old.

Things like companion planting, Parenailian vs Annual, staking things up the right way, separating plants the right way, how to kill poison ivy the right way...etc. There are so many things to be learned. They also learn to respect animals, Bees, and other insects that are critical to the ecosystem. One of the biggest lessons they learn is how to properly identify when something

is in season (taste and smell comes in handy for this) and then how to harvest and store it properly.

Community Awareness

The elementary school next to the facility is directly connected to working in the garden. The Urban Action Institute at the college waives fees for students 60 years or older taking the one credit course which focuses on agriculture and gardening basics. The UAI also promotes the garden regularly. In the past a group from the Worcester Tree Initiative was invited to come teach about planting fruit trees.

Another educational program started was the "SNAP practicum". Run in the fall and then again in the spring, this program trains students to help individuals apply for SNAP benefits as well as advocate for hunger and food insecurity starting locally, and going communally, then "globally".

4.5.4. Food Insecurity

Research had been done previously at the college and it was determined that 1 in 3 students are food insecure. To combat this problem a food pantry had been established, as well as a Hunger Outreach Program. The Food Pantry allows anyone with a college ID card to purchase items from the pantry, and this is not limited just to students. Additionally, the college can offer students emergency funds directly onto their card if it has been determined a lack of food is preventing them from completing class. This is done to be discreet, and not draw attention to people who are using emergency funds for food at the college.

The food pantry is stocked in part from the garden, and items from the grocery store which food pantry staff get. Once a week a single student can take 30 pounds from the pantry or 50 pounds from the pantry for a family. Students normally do not take the maximum amount available but there is a good supply there so students can feel more comfortable taking what they need. The college has also been involved in The Voices of Hunger conferences, where multiple colleges come together and discuss food insecurity, and working to find ways to address it on college campuses.

4.6. Cross Case Analysis

4.6.1. Introduction

This section details the findings when comparing all data from all four cases. According to Qualitative Analysis in the Case Study as detailed in the Data Analysis chapter, careful interpretation of the data, triangulation of analytic techniques, and investigator triangulation are three ways to improve the quality of analysis. We incorporated these methods by grouping cases with similarities and comparing those groups to the others. First, starting with similarities between all 4 cases, next similarities between any 3 cases, then any 2 cases that had similarities, and lastly comparing individual characteristics of cases that aren't shared with each other. Below is a table that outlines this method.

Table 10: The Requirements for Cross Case Grouping

Type of Cross Case	Requirements
Across 4 Cases	Every case involved has a similarity in specific theme or aspect.
Across 3 Cases	Three cases have a similarity a theme; can vary to some degree.
Across 2 Cases	Two cases have similarities. The remaining two may not be similar to each other.
Across 1 Case	A theme exists only in one case.

Each Across Case has a certain number of possible groupings between the individual cases. There is only one possible grouping for Across 4, which would be all four individual cases. Across 3 cases has three possible groupings for similarities between three individual cases, meaning the fourth case that has been excluded does not share that similarity. The possibilities across 2 cases had the largest number of groupings, with 6 possible groups. Finally the Across 1 case contains only individual cases, which excluded the other three from similarities. This doesn't necessarily mean the other three share similarities, as each case could be doing something different for a certain theme.

Below is a table that details what each grouping for each Across case consists of. Due to the large possible grouping for the Across 2 cases, that section is handled differently than the other three across cases.

Table 11: Each Across Case, Possible Groupings, and Individual Groupings

Across Cases	Possible Groups	Individual Groupings for Cases
Across 4	1	[1.2.3.4]
Across 3	3	[1.2.3], [1.2.4], [2.3.4]
Across 2	6	[1.2], [1.3], [1.4], [2.3], [2.4], [3.4]
Across 1	4	[1], [2], [3], [4]

This section summarizes what was found in the cases and reports the findings across all the cases which are the same, different, or were expected but not present in any. Comparing each case study to each other helped uncover patterns and practices that occur similarly in each facility, as well as the differences between them. The purpose of this section was to create a clear justification for recommendations made in the final chapter, Discussions and Recommendations.

4.6.2. Similar Characteristics Across All Cases

The points that all four cases converge on are Education, Materials, Organization, Safety, and Community Outreach (in order of similarities).

4.6.2.1. Optimization

The materials all four cases used shelves/tables in their facility, and manual watering systems were utilized. The only diverange for the watering system was that Cases 1, 2, and 3 also had access to automated watering systems. Regarding safety, all four had locked doors, the main difference was Case 4, which was only for the storage shed not the entire facility (as it isn't possible being a garden). Cases 1, 2, and 3 locked the door of their facility. The final main

similarity was that all had some sort of storage space, the divergence being size and proper usage/utilization. The size of the storage space was relative to the size of the facility, but the proper usage/utilization was not.

4.6.2.2. Types of Education

All four cases had some type of education component, but this is where some of the most similar divergence occurred. Education of people of all ages occurred in all four cases, but there was divergence in how they occurred, in that cases 1 and 4 included college students as well as high school students and middle school students respectively. Subsequently Case 4 also had elderly, non-college students active in their garden. Cases 2, 3, and 4 had education occurring outside of the college courses with the REC YouthGROW. All four cases offered training to new students who worked/volunteered in their respective facility.

4.6.2.3. Food Insecurity

There was not a single component of food insecurity that was present across all four cases. This was due to Case 2 and Case 3 using their facilities for experimentation and research, where the other two did directly address food insecurity. Speculatively this may change in the future, as the manager of Case 2 was open to growing food, and Case 3 had previously grown food and the college itself does donate uneaten food.

4.6.3. Similar Characteristics Across Three Cases

The main themes that emerged across three cases were materials/equipment, training staff/volunteers, structures, automation, plants, records, safety, and community awareness in order of similarity frequency.

4.6.3.1. Optimization

Regarding materials, Cases 1, 2, and 3 all used heating systems, thermometers, soil with peat moss, and artificial lighting - although this was only consistently utilized in Case 1. The heating system was not being used in any of the cases at the time of investigation as it was summer, and a cooling system of sorts was required at that time. These things were not present in Case 4 as it was located outside, rendering the lighting and heating systems unnecessary.

The structure of Case 1, 2, and 3 all used special glass to optimize heat retention in their greenhouse. Automation components consists of heating and watering systems were in place in Case 1, 2, and 3. Similarly the automated heating system was used in all three cases, but the automated watering system were not fully utilized in any cases. The plants grown inside the facilities all looked healthy across Case 1, 2, and 3. Case 4 didn't meet this criteria, and was excluded it was not able to grow plants inside at the time. Records were very limited in either access or availability for Cases 2, 3, and 4, making it difficult to determine optimizing budget/costs. The main safety measure across Case 1, Case 2, and Case 3 was keeping a log of keyholders.

4.6.3.2. Types of Education

While there were some forms of education components across all four cases, it varied enough to group these across three cases. In Cases 1, 2, and 4 there were extra curricular classes available, offered by the facility itself in the form of a program like Plant Parenthood, the Teaching Garden, or occasional workshops. In Case 2, 3, and 4 there were groups from outside of the facility that offered training and teaching. The groups that did this were YouthGROW and/or a club at the college. This put Case 2 and Case 4 at the most educational facilities over all.

Awareness of the facility was noted in Cases 1, 2, and 4 with informational pamphlets or fliers readily available, or some sort of advertising done, as well as the greenhouse club at Case 2. The level of awareness of the facility is where these similarities diverge, with Case 4 being the most involved in the community, and Case 1 being close but lacking. Case 2 had very little community aware done on the part of the facility, although there were fliers for the greenhouse. The main source of community awareness for Case 2 was done by the Greenhouse Club.

4.6.3.3. Food Insecurity

There was no similar components regarding food insecurity that occurred across three different case studies. This was likely limited due to only two cases actively doing anything for food insecurity, removing it from possibly having a similar component across three cases.

4.6.4. Similar Characteristics Across Two Cases

In this section the grouping of cases with similarities is done differently than the previous section. Rather than include what didn't happen in non-similar cases, only the cases with similarities are present are noted specifically. Essentially if something didn't happen in the other two cases it doesn't need to be explicitly explained, or two different things were done. There are situations in which the other two cases are mentioned, either for clarification or to further explain operations, but that is not the standard for this section.

4.6.4.1. Optimization

Structure

Case 2 and Case 3 have large greenhouse areas, giving them comfortable spacing, the option to set up tables to optimize the work area. The differences are in size and physical layout, but are both structures are modifiable and can be removable. Additionally both facilities are connected directly to the college.

Materials

Case 2 and Case 3 have automatic windows systems, the difference being Case 2 did not have that system active. These facilities also had ventilation fans to the outside for cooling, which Case 1 did not have.

Automation

There were no groupings of cases that had automated systems, and utilized them in a similar manner. For instance Case 2 and Case 3 did have automated windows, but only one of them utilized them. Otherwise no other groupings have systems that a third didn't have as well.

Plants

Case 1 and Case 4 grow both food and non-food plants outside when in season, where as Case 2 and Case 3 only grow non-food.

Case 1 and Case 2 had plants hanging from hanging bars inside their facilities.

Environment

Case 2 and Case 3 are both located on the roof of a building, and are connected to the college itself. They have limited access to them, being located outside of hallways, that require a key, and both are not particularly noticeable from the group. Case 2 being significantly more noticeable than Case 3, but could still be missed to someone not aware of what it was.

Sustainability

Case 1 and Case 4 both used some sort of compost, Case 4 using composted plant matter, and Case 1 using a worm farm. The reason Case 1 was not composting plant matter was because the college did not want it to be done over concerns of regular upkeep.

Case 2 and Case 4 were both reusing water in some fashion. Case 2 was reusing water for an experiment which is likely not a permanent occurrence, whereas Case 4 had a rainwater collection system in place and being used.

Organization

None of the groupings of two cases had any similarities between them which didn't also apply to at least a third case. This is likely due to the fact that none of the facilities would likely be unorganized, since they're all being run for relative efficiency.

Records

Case 1 and Case 3 were both created in part with the use of some grant. It is unclear if this was also the case for the other two cases, due to a lack of available records.

Safety

Case 1 and Case 2 have security cameras in place, the difference being Case 1 had a camera that was inside the facility and had an active, live feed on YouTube. The camera for Case 2 would be from the college, not specifically for the facility.

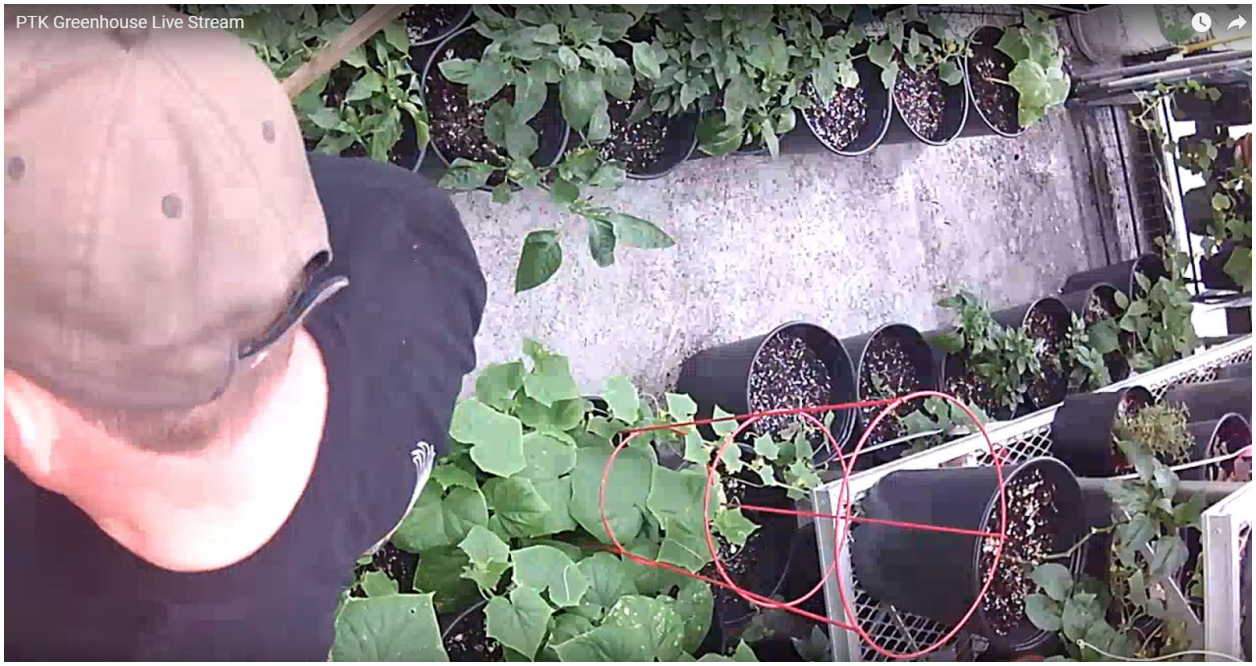

Figure 19: Screenshot from A PTK Greenhouse Live Stream

4.6.4.2. Types of Education

Experiments

Case 2 and Case 3 had classes and experiments held by the colleges.

4.6.4.3. Food Insecurity

Case 1 and Case 4 both not only have a food pantry on campus but also offer SNAP and WIC program information and help.

4.6.5. Different Individual Characteristics Across Case Studies

The difference between individual cases is more related to how the facilities are run, and exist to address specific challenges. For instance Cases 2, 3, and 4 don't need to utilize artificial

lighting, where Case 1 uses consistently, due to the limitation of sunlight. As such, there are more data points to note for individual cases, that didn't occur in the other three cases. For instance Case 1 uses natural plant nutrients from the worm farm, since they don't have access to a plant matter compost. To detail these findings each case is listed individually with the findings that weren't present in the other three.

This section details what was specifically different about the individual cases. Similar to how the Across 2 case analysis is set up, the cases are sectioned by the individual case. All the similarities with other cases are removed to exemplify what these cases are doing that is unique. These are condensed to remove non-important themes to be more concise.

Table 12: Lists Cases and Themes That Were Present in Their Individual Cases, and the Explanation of These Findings Compared to the Other Three Cases

Case and Themes	Explanation of Uniqueness
Case 1 ● *Structures* ● *Materials* ● *Plants* ● *Environment* ● *Records*	The facility is a small, single, rectangular room, located on the ground level, next to (not attached) to the college. The materials/equipment used included natural plant spray, and plant nutrients from the worm farm, a water filtration system, a net for vertical plant growth. This case had the most records with a food log, work task, and fundraising information. Two types of specific plants were sometimes grown together as they both benefited growth wise. To combat pests inside the facility specific bugs (ladybugs and praying mantises) were raised. The plants outside the facility did have occasional signs of compromised health, specifically being eaten.
Case 2 ● *Structures* ● *Materials* ● *Training Staff* ● *Community Awareness*	The facility has four square rooms, use hanging fans, and has an alarm specifically for when the temperature got too high. The program Plant Parenthood is active and occurs regularly, at the beginning of each school term. Inside the facility there is troubleshooting guides for common issues, and how to solve them.
Case 3 ● *Structures* ● *Materials* ● *Plants* ● *Safety*	The facility has 2 rectangular rooms, a swamp cooler, although it was not being utilized. There are also chairs inside the facility. There were three unhealthy plants inside the facility. This facility also had a sprinkler and fire alarm system, as well as a fire extinguisher.
Case 4 ● *Structures* ● *Materials* ● *Plants* ● *Environment* ● *Sustainability* ● *Community Awareness*	The facility was a large open area being a garden. It had a compost section, a hoop house that wasn't being utilized, and was the only facility that was ADA Compliant. Being a garden it uses natural pest control and natural pollination, where the other cases either didn't require this or had to implement it on their own. Additionally, ergonomic tools, a v-troth, compost containers that were in use, and general garden supplies. This was the only facility where a device made from recycled materials were noticed.

4.6.6. Conclusion of Most Similar and Most Different Cases

Across these four cases there are more differences between them all, rather than similarities. The amount of similarities between cases diminishes as more cases are compared, meaning there are more points in Across 1 than in Across 2, and there are more points in Across 2 than in Across 3, leaving Across 4 with the least similarities.

Comparing all the possible case combinations and occurrences of similarities, it can be seen that Case 2 and Case 3 are the most similar. The least similar are Case 3 and Case 4. Case 1 is most similar to either Case 3 or Case 4. These findings can be seen in the following three tables. Case 4 is the least similar facility compared to the other three, as it had a total of 20 combination occurrences. The most similar case based on combination occurrences is Case 2.

According the occurrences of noticeable individual differences, as seen in the table above, Case 1 had the most individual differences, and Case 2 had the least. Case 3 had a similar amount of individual differences as Case 2, and similarly with Case 4 compared to Case 1. This may give credence to Case 2 and Case 3 being the most similar, but doesn't apply to the logic of Case 1 and Case 4 being similar. This might indicate the divergence occurs the most with Case 1 and Case 4.

Table 13: Similarity Frequencies Noted Across All Possible Case Combinations

Case Combinations	Occurrences
1.2.3.4	7
1.2.3	8
1.2.4	2
2.3.4	2
1.2	2
1.3	2
1.4	8
2.3	9
2.4	1
3.4	0
1	29
2	31
3	28
4	20

Table 14: Frequency Two Specific Cases Had Similarities Between Two, Three, and Four Case Combinations

Combination of two cases	*1.2*	*1.3*	*1.4*	*2.3*	*2.4*	*3.4*
Frequency	19	17	17	26	12	9

Table 15: Occurrences of Noticeable Difference in Individual Cases

Case Number	Occurrences of Noticeable Differences
1	15
2	5
3	7
4	13

A full list of similarities separated by number of cases they occur across, and by theme is located in the Appendix F.

5. Chapter 5: Recommendations

5.1. Discussion

This section goes over the analysis we made from our results and how we translate it into tangible recommendations. Along with these our recommendations there is insight given from case studies. These recommendations will focus primarily on each theme for the three components, but there are also additional recommendations that don't necessarily fit into those sections. Additionally, these recommendations may come from background information or personal insight, not necessarily directly from the findings.

A key take away from the findings came from one of the managers we interviewed. It was noted that if an organization was looking to optimize growing food, a greenhouse wouldn't be the best choice. A better way to do this is by using freight farming. Freight farming is the next step from a greenhouse, away from a garden; a modular freight container with no windows, filled with automated grow lights, watering, and temperature systems. This optimizes space, growing season, and efficiency, but it targets specific plants to grow the most amount of food and keeping the systems the same. The service is offered by a company called Freight Farms (www.freightfarms.com), it has a section for colleges, and offers training in Boston, MA. One of the points noted on the site regarding colleges is there is an option for the college to own it which would enable a college to customize what's grown and if they want to associate education or jobs with it. What would it take to make a single freight farm cart? This might be the next stage to come from this project.

Originally this project to address food insecurity started specifically for QCC, but this would be applicable to all the case studies. We discovered this as we were going through the data and noted each place did things differently. With that said these recommendations are directed at QCC, but general recommendations will be applicable to any organization looking to start a greenhouse with an education component to address food insecurity.

None of the cases had any sort of renewable energy system like solar panels or wind turbines. This may be due to having the energy consumption handled by the college, as well as not having access to the facility's usage (We will use the term facility to cover greenhouses and gardens). If the facility had to handle this, there would be records available, and renewable energy may have been considered. Since there were no cases where renewable energy was present no recommendations come from the cases. Rather recommendations regarding renewable energy come from personal opinions, but it would logically be a worthwhile pursuit for a few reasons. First, it would reduce energy consumption by the facility, which is good for the environment. Second, it would benefit the college if the facility was creating a surplus of energy. This may entice colleges to encourage a greenhouse being constructed as it would help address costs. This pursuit would require money to get these things at first but would pay itself back overtime and then create a surplus of money. If the greenhouse doesn't operate based on profits and has to raise its own money, this might not be a priority compared to other improvements.

5.2. General Recommendations

After reviewing the data from the cross case analysis a checklist was compiled, located in Appendix G, which gives a visual aid to what components for each pillar and theme were present in each individual case. Alongside the individual cases there is an Ideal Case, which is what we believe to be the components for an optimized greenhouse that involves education and addresses food insecurity on a college campus. The following section details the check list in Appendix G.

5.2.1. Optimization

Structure

The structure should be large enough to have rows of tables, similar to the image below. Another option is to have the tables lining the wall, with the center either open or with a center table. The row-design is better for having more available table space to tend to plants individually. The main constraint is optimizing the structures layout while maximizing sunlight.

Figure 20: Case 3 Greenhouse Layout, Using Multiple Tables are Varying Levels

The layout of the tables also needs to take into consideration accessibility, and the staff's ability to move around and not block pathways. Using vertical space, such as multiple levels of tables will help optimize yield, but it will also require the use of artificial lights. Cost would come into play to determine which is better for the facility, but if yield is more important the lights are better. Having the lights automated and easily programmable will be important, and this principle applies to all systems in the facility.

Systems should be situated for efficiency; for instance, avoid using two heaters when one can be used. Positioning heaters in the greenhouse to maximize their output usage would help both maintain a reasonable cost and work to ensure an equal amount of heat is distributed to

plants throughout the structure. If the greenhouse is sectioned into multiple areas, positioning the heaters to work together would also help to promote effective heat distribution.

Creating a "mud room" at the main entrance of the facility is important. Doing this will reduce the likelihood of outside pests coming in and good insects escaping. It will also help keep temperatures regulated, reducing energy consumption and improve plant growth. This entrance section of the greenhouse would be best at the side that would get the least amount of sunlight. This could be difficult to do as there are likely restraints on where the structure would be placed, but this would be the most optimal. This room should also be outside the greenhouse, as a separate part, to maximize the area inside for plants.

There should be a drain in the floor of the foundation, to make it easier to remove water, allowing the facility to be able to be more easily cleaned. Each section of the greenhouse should have a sink to wash plants, and they should have a sediment trap. A sediment trap allows things like dirt or clay to be removed from the water into a separate container, reducing the amount of build up that occurs in the pipes. This is a preventative measure that may also allow for sediment collected to be reused, further reducing costs.

Having a modifiable structure would be beneficial for optimization. Specifically having the inside of the structure modifiable would allow for setups to change. This would facilitate the change of plants, either the size of them as they grow, or when different plants are being grown. Having sections that can be added, removed, or changed in size would create different rooms, while inside these rooms would have hanging bars to move plants and lights, and movable tables and shelves.

A composting area would be beneficial, especially if it is in sight and constantly taken care of. The issue would be the smell, but if it is constantly being aerated the smell should be negligible (Richard, 1996). While doing this would be beneficial, it would not be something that should be started after a new facility is built, rather than at the same time, since this will be an extra area of training that would interfere with the initial training and learning of the new facility.

Materials

When implementing any sort of equipment or deciding on what type of materials to purchase, make sure things aren't difficult to maintain or upgrade. This will avoid them being dismissed as easily, or ignored until they become an issue of their own or an issue for something else that needs to be maintained or upgraded. If things are too intertwined and difficult to maintain it will create a greater "cost" (money or time) for each component to be handled.

Benches and tables are one of the most important things inside a greenhouse, behind the plants and pots. The tables used should be grated, adjustable, and sturdy. Adjustable tables can also have multiple levels, optimizing available space. On the tables large tubs can be used to place potted plants in, to reduce the mess on the floor. The image below is an example of the table and tub. The table below doesn't allow for adjustable height, which would be ideal.

Figure 21: Grated Table with Potted Plants and A Tub

If the greenhouse will have sinks with plumbing, having a sediment trap or filters is important to reduce build up in the pipes. These can be purchased or made. If these are used, make sure cleaning is accessible and easy, and doesn't require any knowledge of plumbing. Having the necessary watering tools is important, such as watering cans and hoses. The hoses should be long enough that they are not limited in their range, but they should not be too long that the excess length becomes a hindrance. Additionally, hoses that are too long may develop leaks, and it will be more difficult to find and fix them, or replace the hose. The watering cans should be large enough in volume that multiple trips to fill them aren't necessary, but not too large that their size is a hindrance for storage.

Artificial Lights are necessary to optimize a greenhouse plant growth. This is especially true in a situation where there will be multiple levels of plants being grown, either on the shelves or vertically. These lights should have the same type of bulb, specifically LED to reduce cost and

maintenance. Some types of bulbs are more difficult to handle, and are not recommended. The size of the lights should be taken into consideration to make sure they don't take up too much room, are able to be easily moved, but are not so small they are inefficient. This will require independent research of the lights used.

Thermometers and a temperature alarm are both important for ensuring the temperature and humidity in the greenhouse does not exceed what is safe for the plants. The thermometer should be able to be set to a specific temperature, and the alarm should go off if it becomes too hot inside. Once the temperature has reached the set point the windows should be able to either automatically or manually be opened. Additionally, window-ventilation fans and hanging fans should assist in circulating and expelling the heat, until the greenhouse reaches its desired levels. The hanging fans should utilize the hanging bars, previously mentioned.

Having peat moss dirt for growing plants is important, as peat moss retains nitrogen the plants can absorb, and also helps combat overwatering as it holds moisture well. It is worth noting that peat moss is not considered a renewable material due to the time it takes for peat moss bogs to generate the peat moss that is harvested from them. Research into supplemental materials for this is recommended, as alternatives come with varying costs and constraints. Furthermore, having organic plant spray to promote health, combat disease, and plant infestation is important. Independent research into this is required as different plants may need certain types of spray, and it's possible that this can be made in house.

A water filtration system would be beneficial to remove both materials and chemicals that are bad for plants. Having filtered water and including plant food supplements with it would

further promote plant health and growth, ensuring the plants are only getting the minerals they require.

Shade cloth is an important material to have available and utilize if there is too much sun. This will help reduce plants getting too much sun, and allow for the control of light. If the amount of light plants need has been researched, it can be displayed by the plants and tracked. Using a light sensor would make it possible to track this information. More research would need to be done for this if it is an idea that is being considered, and a decent place to start is at the following website: https://blog.mide.com/how-light-sensors-work.

With enough room in the facility foldable and solid chairs are recommended. This will allow people to sit and work with plants and not get tired of standing or kneeling. To further reduce fatigue, ergonomic tools and aprons are also recommended.

Figure 22: Ergonomic Hand Rake

Automation

The five main systems that should be in place and automated are lighting, watering, heating, cooling, and windows. Along with artificial lights, this would require drip-watering system and piping. The heating and cooling system would need automatic windows (which can also be used manually), window fans, hanging fans, a heater, and a thermostat. Additionally, it would be extremely beneficial to have an alarm system that indicates if there is a problem with any of the systems.

To reiterate, these systems should all be easy to access, maintain, and understand. There should be training and troubleshooting guides for any system, especially that new staff can understand. This way there isn't a single person in charge of critical components, that if unattended to could harm the plants or patrons.

Plants

Research types of soil that are best for the plants you're going to grow. We didn't look into this because it's too specific, but an example would be growing tomatoes in a combination of compost and inorganic fertilizer to produce a higher yield (Brunetti, Traversa, De Mastro, Cocozza, 2018). Doing this for all of the plants that are being grown will help determine the best general soil to purchase for the most yield and healthy plants. Additionally being able to test and manage the pH levels of the dirt is important, and should be kept track of.

Determine what wavelength of lights works best for certain plants, which will require research for each plant. While this isn't necessary, it would improve the health and yield of plants, and could potentially improve energy consumption as the types of lights needed may be

more energy efficient. Knowing this may also help determine what plants should be grown together. Alongside lighting being a factor, certain plants have been shown to have companion plants that improve growth. Many of these can be found on the Farmer's Almanac website, at https://www.farmersalmanac.com/companion-planting-guide-31301.

The plants grown should obviously be researched for information on growing, but research should also be done to determine what plants are desired and consumed the most by patrons of the greenhouse and food pantry. Along with this a record should be kept that keeps track of what plants are being grown, what plants patrons want, and what is being wasted. These records would be best suited for the food pantry. Using non-GMO organic seeds has benefits and drawbacks, as GMO non-organic seeds may produce larger plans but draws negative connotations. Due to the perception of the public it is likely the best to grow non-GMO organic seeds, as people may be more interested in consuming these plants.

Maximizing space inside the greenhouse will be a necessity, and as such plants should be grown both inside and outside. Determining what plants can be grown outside during what seasons will be important, and with this additional measures will need to be taken to ensure they are healthy. Most likely the plants that would be grown outside should be flowers, that can stay outside. Growing plants outside then bringing them inside exposes the inside of the greenhouse to pests and diseases that may have not traveled inside on their own.

Environment

For a greenhouse with the intention of attracting attention and being accessible to the community, it should be located both on the ground level of the area and somewhere in plane

sight. This will not only allow people to more easily access it, as it won't require them to travel through a building to get to, but it will also make it a centerpiece of the area it is located in. If the area is well maintained and active the environment should look nice and inviting.

More importantly though, the greenhouse should be in an area that gets adequate sunlight. Too much sunlight is not necessarily good, but having too little sunlight is probably worse, since making up for the light forces the requirement of artificial lights.

Having the greenhouse be on the ground level comes with issues such as pests; these can be from humans, animals, or insects. To combat insects it is advised to use some sort of natural pest control. Inside the greenhouse, having beneficial insects specifically to combat pests is important and will require research to determine what is needed. Having some sort of spray that is non-toxic to humans is vital.

To combat pests for plants that are grown outside will require different tactics, as these factors are likely to be more varied than what occurs inside. People and animals may try to take plants or food that is grown outside. Animals such as birds may be deterred by using fake owls, and humans are likely to be deterred with the use of a camera system outside. Pests will require general pest-control bug spray. As mentioned previously, the only plants grown outside should be non-consumable plants, which would reduce the need to have special plant spray that is non-toxic for human consumption.

Sustainability

Plant matter compost would benefit the facility, as long as the system is properly maintained and aerated to avoid generating a noticeable smell. Composting containers come in

various shapes, which can be easily rotated. One such container, called the Yimby Tumbler Composter, easily rotates, and offers two chambers to separate newer and older compost. Again, if the system is accessible and easy it will be easier to maintain and utilize, and there will be no smell. Along with this, continual usage of a worm farm is recommended, as there was obvious positive results based on the experiment that had already occurred at the original QCC greenhouse.

Recycling rain water is recommended as it will help conserve water. If the rain water is filtered it will improve its benefit on the plants it is used on, as there will be less contaminants. Using recycled materials such be used whenever possible. Things like soda bottles can be used as pots or containers, but any opportunity to create zero waste is recommended. Costs can be reduced by reusing things, and doing this would give clubs or community activities things to do to get them more involved in the greenhouse. Not only will they be helping the greenhouse while having fun, they will be helping the environment by reducing waste.

Using some source of renewable energy may benefit the facility, but we cannot make a decisive recommendation in that regard. It seems likely this would improve the energy consumption of the facility on average, especially using solar panels as long as they don't impede on the greenhouse's sunlight. Wind turbines may be helpful as well, especially if the area is generally windy.

Organization

The area of the facility must have storage area, as it is important to keep the greenhouse organized, clean, and safe. Using shelves to store materials like pots, containers, and plant food

is good. Tools, especially long ones, like mops or rakes, should have a storage area to keep them organized and in good working order. Nothing should be laying in a corner or piled up in an area it doesn't belong. Ensure there is adequate space set up for storage, and a plan for where things will go. This goes into safety as well, since it will improve prevention of things being stolen, and help ensure that people don't get hurt.

It is also important to make sure the inside and outside of the greenhouse are clean and organized. The outside area should be clean to make it look presentable, and the inside should be clean to make sure no one gets hurt. Additionally, having things organized will make it easier to work efficiently, so people aren't having to maneuver around people or supplies.

Records

Keeping records is an important part to optimize a greenhouse. While there can be too many records kept, causing extra managerial work, having too few records is probably worse. There should be records for costs of supplies, what supplies are available (how many pots, how many bags of dirt), the cost to operate the greenhouse, energy consumption, what plants are being grown, the yield, what is consumed, what is thrown out, and work tasks. Having these documents can help improve how things are managed and can be used to make executive decisions, such as what plants to grow and when.

Additionally these documents should be available for the greenhouse manager, the PTK officers, and administrations. Having clear access to records like the energy consumption and costs can be used to make decisions to improve the greenhouse, such as implementing renewable materials. Along with these records, a compendium should be created. This document is

discussed in the education section of this chapter. Any experiments that have been conducted should be reported on and a record of this should be kept. Doing this will allow for either further experiments or making sure experiments aren't duplicated.

While this ties into safety, a record of who has the key to the facility is important to have. It will ensure no unauthorized persons can enter, and may create a sense of responsibility and accountability for the person with the key. The facility should be run like a serious business, even if it's not for profit. This will help it be more optimized as there will be statistics.

Safety

Having the greenhouse more visible will impact safety. Making it more visible could help reduce the chances of theft, but also makes it noticeable to criminals. For this reason having a camera security system is recommended. The vicinity could be monitored for human or animal theft, and there's also an opportunity to improve monitoring plants and raise awareness by creating a live stream online.

Another important safety recommendation is to include a fire alarm, a sprinkler system, and to have a fire extinguisher readily available on the facility at all times. To further improve safety having a lockable door is obviously important, and the key should be logged at all times.

Other Recommendations

Don't focus solely on optimization at the expense of education, as education helps to combat food insecurity but will also improve optimization. For instance, having an automated watering system will optimize plant growth, but it will reduce the education people have

regarding watering plants, and reduces their personal interaction with them. This would in turn have a negative impact on food insecurity in the long run, as people will have a more limited understanding in how watering plants is done and how important it is. Instead, keeping the facility sub-optimal by not having a fully automated watering system improved education and food security.

5.2.2. Types of Education

Training Staff

A plan should be created that covers everything people working in the facility would need to know. Whatever training has been done in the past should be recorded and organized into a document. This will make sure people are aware of everything that needs to be done, and it can be tracked. Additionally any questions about specific things can be looked up easily. This would be best to keep at the facility, but copies should be available online to staff and volunteers.

Have a readily accessible troubleshooting guide for common problems inside the facility. Having the guide on a section divider, or located with the records kept inside the facility would be the most beneficial. For an example of what one of these would look like, see the Figure 23 below.

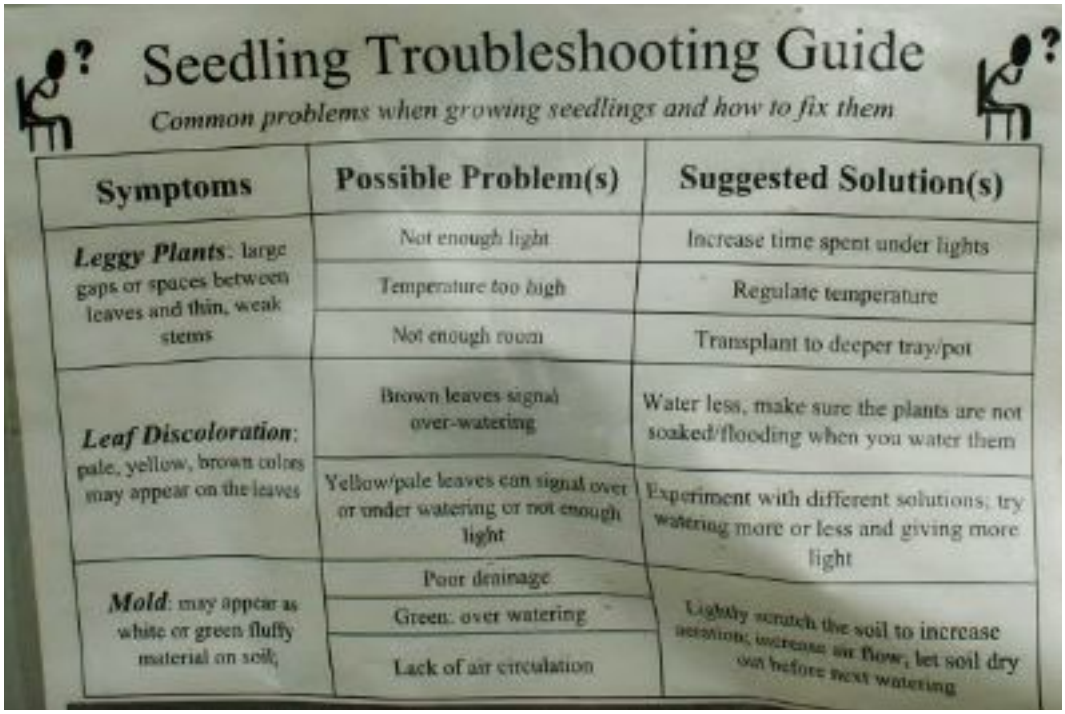

Figure 23: Photo of Troubleshooting Guide Located in Greenhouse of Case 2

Experiments

To improve the greenhouse's optimization it would be beneficial for the staff to perform experiments/tests on plants to get a better understanding of them, but also to determine practices that may be beneficial - or would be detrimental. Doing this should also be done to improve the education available to patrons of the greenhouse. To do this it would be advised to keep a small area in the back, or dedicating specific tables, with labels and information about the plants and the experiment throughout the greenhouse - but separated from the food that is being grown. This is not a major recommendation though, as this will hinder the production of food.

Some sort of compendium of plants being grown, information about them, how they grow, what sort of things to look out for regarding their health, how to handle problems the

plants might be facing, their growing cycles, how much water they need, and even things like what other plants they grow better or worse within the same soil. A log should be kept with this to comment on how well the plants are doing, any sort of experiments that are done with them, the results of the experiments, what worked and did not work, and other comments that make growing go better. Having a compendium available will make it easier to troubleshoot issues for staff in the greenhouse.

Community Awareness

The major aspect to improving the community awareness of the greenhouse would be to get involved with the Regional Environmental Council (REC) YouthGROW Program. The REC is a grassroots program that promotes fair and equal access to healthy, sustainable and affordable food for all, and the YouthGROW program is "an urban agriculture-focused youth development and employment program for low-income teens." This program allows members to gain leadership and job skills, while participating in workshops, internships, and community service (Brimmage, 2019).

This program would bring more awareness, volunteers, and insight into the greenhouse. The YouthGROW has been active at the facilities of Case 2, 3, and 4, only using space when available. The members and staff of this program would be very helpful to have working in the greenhouse, as they would bring experience and insight to how to manage and work in the greenhouse. This is especially true since they have been working in large greenhouses and gardens for years already. Having them involved would also give insight into hands on education that may have not been experienced previously.

Outside of the greenhouse advertising to people that aren't at the college, such as is done in the Case 4 Garden with the elderly citizens of the community. This is likely to bring in people who are interested and passionate about working in a greenhouse, and may have experience, knowledge, and insight that would be invaluable. Starting a Greenhouse Club on the campus would also help promote and staff the greenhouse. These two options will come with an extra level of complexity as it will bring in people who have very little accountability regarding the greenhouse or the college, so this would need to be held for serious consideration.

An additional club or group that could be made, which isn't necessarily directly related to the greenhouse would be a Bee Club. This could invite people who are off campus to be involved in raising bees on their property - off college grounds - which would help increase the native bee population. The greenhouse would act as a hub for the club members to meet, especially if there are flowers being grown on the outside as previously recommended.

Improving the greenhouse's website to function properly, and to include the live stream from YouTube could also be beneficial to getting people interested. It would also make the information available for anyone to see, so someone who is interested in greenhouses or working on these sorts of systems may find it worth getting involved in.

5.2.3. Food Insecurity

The number one recommendation for addressing food insecurity on a college campus, using a greenhouse is having a food pantry. Without this it seems likely the effort would be largely in vain. Having a food pantry on campus is critical for the success of such a program. This requires a lot of work, money, time, and man-power to start and operate, but without a food

pantry addressing food insecurity on campus is much harder. This should be a priority over having a greenhouse, if not a tandem priority.

As mentioned earlier, growing food to combat food insecurity can be done without greenhouse, and the most optimal way to do so is not with a greenhouse. A greenhouse is good for addressing food insecurity through both growing food and creating an environment for learning, and as such should be a priority over optimization.

Creating a Food Insecurity Task Force could help address food insecurity. This should be made up of members of the greenhouse staff, as well as other members and students on the campus. The Task Force should look to do research about and raise awareness of food insecurity on campus, and work to create nutritional education and assistance programs. Some other things they could do are as follows, but there are boundless things a group of people could do in this position;

- Work with getting SNAP benefits in place for people,
- Pamphlets in the greenhouses,
- Nutrition Education and Assistance Programs information should be included in all information distributed by the greenhouse,
- Work with food pantry to optimize their stock and food turnout to ensure as many people are getting the help they need as possible.

There is a conference called Voices of Hunger Summit, which is hosted by UMass Lowell. The event brings college and community members together from across the region to discuss food and housing insecurity, specifically on college campuses. There are keynote presenters with backgrounds and experience on these topics as well. Additionally there are

scholarships available for multiple people to attend this conference. As this aligns with the goal of the greenhouse it would be recommended to research this conference more. Information from the previous (2019) summit can be found at https://ccsne.compact.org/campus-food-security/2019-regional-campus-food-insecurity-summit/.

As the greenhouse website had been previously mentioned, if it is available to the public and not just staff, it should have information on education and assistance programs. Especially if there are courses, programs, and groups offered on campus. More so if the website is being promoted alongside the greenhouse itself. This will help people get information regarding food insecurity in a discreet way, and have it all available in one place.

5.3. Most Vital Recommendations

Below, in Table 16, are the three main recommendations for each component, which our team has deemed to be the most vital for optimization of the greenhouse. Additionally, as previously mentioned, all of these recommendations should be done in a way in which they are easy to maintain, and are not intertwined so deeply with other processes or systems as problems with one aspect could cause problems with another.

Table 16: Key Recommendations by the Three Project Components

Optimizations	● Large, modifiable, organized structure, with adequate sunlight and is safe, ● Automation of heating, cooling, watering, and lighting systems, ● Composting of plant matter.
Types of Education	● Create a training program, which guides staff how to maintain the facility and plants, ● Create a greenhouse club, ● Connect with the non-college community by getting involved with REC's YouthGROW program.
Food Insecurity	● Set up a food pantry, ● Start a Food Security Task Force, ● Incorporate national food assistance programs like SNAP and WIC, ● Get involved in the Voices of Hunger Summit.

Research is important on all levels, and should be done by the manager and head staff of the facility. We always recommend to research things yourself to unearth things we didn't find, or couldn't touch on. There will always be new technologies and new things added that will update the industry. Some things will become outdated, while other things will stand the test of time.

6. Chapter 6: Conclusion

6.1. Possible Outcomes

After reviewing all of the data and findings we believe that if QCC at least implements the 10 recommendations we've made, their future greenhouse will be positioned to seriously impact food insecurity on campus. Having a large, organized greenhouse that gets adequate sun, is able to be modified to optimize space, which utilizes automation heating, cooling, watering, and lighting systems. This will ensure the plants that are researched and grown for food consumption will yield the most possible amount of food. Creating a training program to adequately take care of plants and the facility will ensure all processes are uniform and maximize efficiency in the greenhouse.

Implementing a training program can serve as a basis for an education program. Having a larger community outreach that involves college students through clubs and members of the non-college community through YouthGROW would greatly improve the awareness of the greenhouse. Additionally it will help bring more awareness to food insecurity throughout the community. If QCC starts a Food Security Task Force, incorporates more national food assistance programs, and gets involved in the Voices of Hunger Summit they will begin to approach their goal of addressing food insecurity on campus. This is because there will be missions in place to both bring the issues regarding food insecurity to light, but also address them.

Following all of these key recommendations will position the greenhouse to get a strong foothold against food insecurity. This is true even more so if they follow the specific recommendations detailed in the recommendations chapter. Following the check list located in Appendix G for an Ideal Case would create the optimal greenhouse to address food insecurity, while employing an education program.

Additionally, as mentioned previously in the Recommendations chapter, these recommendations would practically apply to any organization looking to make a greenhouse with an education program to address food insecurity, including the other cases studied for this report. If a college outside of Massachusetts were to follow the recommendations, their biggest issue would likely be related to their environment, both physically and culturally, especially regarding the college community. With those factors taken into consideration this project serves as a blueprint that can be used anywhere with minimal changes.

6.2. What Could've Gone Better

This report would benefit from a few select aspects. Mainly these revolve around resources, as time and labor were the greatest limiting factor. With significantly more time and a larger, dedicated and focused team, this project could have been more expansive. Having a much larger group of case studies, including businesses, would improve findings regarding optimization as there would be a wider variety of greenhouse programs, setups, and organizations to collect data from.

Since there was a limitation on documents, and facility run education programs were not common, this aspect of the analysis was too limited. This aspect was definitely the biggest issue encountered regarding recommendations. Had more educational documentation been available this project could have been more in depth with how to optimize a plan for education, but also how to setup a structure to facilitate learning better.

Data collection in this project was arguably limited, as the two main sources of data were anecdotal and subjective. Since the bulk of the data was from interviews, there was bias and limitation that was not completely eliminated, as statistical and logistic records were scarce. The observational data was largely subjective, as things were likely missed, limiting the data that was analyzed. Again, having documents like energy usage, operational costs, and grow logs would have helped improve the analysis of this data.

Expanding the project to include a larger number of case studies would further validate the findings and recommendations made in this project. Due to the regionally limited case studies it is possible that the practices employed in each case study are not wholly representative of a greenhouse or that education components are optimized/beneficial to areas with largely different demographics. In other words, what occurs in a greenhouse on a college campus in Central Massachusetts is likely to be different in many ways from a place in rural Iowa for example such as a local business greenhouse. Including recommendations from greenhouse facilities located in varying geographical regions that have at least two components of our project would expand and/or fine tune the findings and recommendations we have generated.

Similarly, if we repeated this project in a completely different area and studied the components of its college campus greenhouse/garden (comparing new findings and

recommendations that result from them), with its education plan and food insecurity solutions, we could create a list of recommendations that might backed by two geographically and otherwise different case studies.

Having background information and a methodology already in place that would have facilitated this project, as opposed to generating our own, would have allowed for more time to locate and interview a larger number of cases. This could have also freed time for analysis of more cases as well. This again deals with time and labor factors limiting the project. Otherwise this project accomplished what it set out to do with very few limitations.

6.3. Next Steps

Moving forward with this project, there are a few directions that future teams could take in order to continue to study greenhouses that address food insecurity:

- Repeat this project with Case 2, 3, 4, and the new greenhouse that QCC builds.
- Expand this project to include a larger number of case studies,
- Repeat this project in a different area of the country or world and compare the results from this project to cross reference the findings and recommendations.

When this project is repeated with a more expansive base of cases to give greater breadth and depth of the data collected, and would improve the validity and number of key recommendations as well. With the new QCC greenhouse is included in a follow up study it would reveal the improvements generated by the recommendations, and how much of an impact they made on food insecurity on the campus. Once this occurs it would give a positive insight

into effective ways food insecurity can be addressed in communities, and specifically on college campuses.

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Appendix

Appendix A: Interview Protocol

Interview Protocol

Beginning Script

Hello! My name is _____, I'm a student at Worcester Polytechnic Institute studying _____. I'm part of a team doing a study on to learn more about greenhouses, how they operate, and their relation with food insecurity and education plans. Thank you for taking the time to talk with me today. The purpose of this interview is to learn about the history, functionality, logistic, and physical components about your greenhouse. We are also looking for insight into optimization, where problems & solutions arose, and recommendations in regards to those as well as education plans and food insecurity plans that you may have implemented or know of.

We want you to feel comfortable saying what you really think and how you really feel. If it's okay with you, I will be recording the audio of our conversation since there might be things our notetaker will miss and will want to review later. Everything you say will remain confidential, meaning that only myself and my teammates will be aware that these answers are your own - the purpose of that is only so we know whom to contact should we have further follow-up questions after this interview.

Before we get started were there any questions you have that I could answer?

Questions

Background on the greenhouse (reason for its existence, who it's for, what went into creating it)

- What is the background of your Greenhouse, was there a specific purpose for it?
- What was the target demographic for the greenhouse when it was first proposed? Has it evolved since then, if it has how so?

Demographics of the greenhouse users including food insecurity statistics or insight

- Can you describe what an average greenhouse patron is like?
- It's projected that food insecurity affects 25 to 50% of college students; what types of programs are available for people affected by it in this community?

Who runs and operates the greenhouse (such as staff or volunteers)

- Who runs and operates the greenhouse?
- What would you say the percentage of staff to volunteer is? Does it fluctuate? Is there an ideal range?

Operators' expertise and experience

- Operating a greenhouse probably requires some skills, can you explain what skills or expertise you look for in an operator?
- What sort of skills do people develop working in a greenhouse?

How the greenhouse is run (physically and organizationally; structure, location, cost, plants grown, systems used, security measures, energy consumption, how logistics and statistics are collected/recorded/stored)

- What does a typical day look like?
- What does a non-typical day look like?

What has and has not worked

- From the beginning to the present there must have been some successes and failures. What of those stand out the most?
- Are there any on going issues you're still dealing with, and if so what are they?

What they've learned

- What have you and the rest of the staff learned?

What could improve their greenhouse

- If money or time wasn't a factor, how could this greenhouse be improved outside of creating an entirely new one?
- With money and time being a factor, what would be considered a critical improvement at this point? Is this something you expect will be implemented and achieved?

What sort of education component they have in place

- Is there any educational component associated with the greenhouse, outside of being on a college campus?
- What benefit does/would an educational component have on the greenhouse itself, the staff, and the patrons?
- Are there problems or hindrances that come with having this component?
- If there is an educational component, how was it designed and implemented?

What suggestions/insight they would have for other greenhouses

- What suggestions do you have for other greenhouses?
- Is there any insight you would like to add?

- At this point, is there anything you think we missed, or anything you expected me to ask that I didn't?

Ending Script

<interviewee's name>, that's all of the questions I have for you right now. I want to thank you very much for your time, it is truly appreciated. All of this information will be extremely helpful. After reviewing all of this with my team we may have additional questions or need to clarify information, and may need to contact you again. Additionally is there anyone else you believe we should speak to regarding this project?

If not then we're all set. Thank you again, have a great day!

Appendix B: Observational Data Collection Protocol

Observational Data Collection Protocol

This document will outline the observational data that will be collected during the interview phase of the project. This data will include photos primarily, but also videos if necessary. Prior to the data being obtained approval will be obtained to ensure everything is fine to analyze.

There are 5 components (detailed below) that data will be obtained for; greenhouse structure, plants, systems, environment, and other items of interest. These components will be supplemental to the interviews for making recommendations for optimization. The details below explain the "of what" and "for what" for these components. Many of the photos taken will cover multiple components, but some may be needed for more focused aspects.

1. Structure

Structural observational data includes the physical structure of the greenhouse; the outside, the inside, the layout, set up, materials used.

Physical Structure (outside and inside)

- Style of greenhouse
- Signs of repair
- Signs of damage

The flow of the layout;

- how benches are placed,

- how those benches are set up for growing, - Are there benches bisecting a path for instance - which can be detailed regarding the reasoning behind a layout that would be counter intuitive.

The physical materials;

- the quality,
- places wear is showing. This might indicate greater frequency of use, which could help determine if the quality of an object (for instance) would need to be greater. This would also be insightful for layout optimization; is this a barrier for an optimal flow.

These are collected to determine if there are ways a greenhouse can be set up that are or are not optimal. Along with some of the examples given above this data will be collected to help determine what sort of materials and layout works or is a hindrance. This will help inform decisions, potentially across multiple areas.

2. Plants

This consists of anything that is grown in the greenhouse; fruits, vegetables, herbs, or flowers. We will collect the following.

- Where the plants are being grown
- What the plants are being grown in.
- The quality of the plants - if they look healthy for instance

These will be collected to give insight to if plants are growing well in the system they're in, the cycles they're grown in, if there are plants that are easier to keep together or not.

3. Systems

Systems are types of processes or mechanisms that contribute to the production of the greenhouse. This includes watering, fans, lighting, as well as how plants/materials are handled, stored, cycled, and so forth. We will collect the following.

- Watering
- Lighting
- Temperature
- Surveillance/Security
- Storage
- Growing
    - How the systems are integrated
    - Quality of care for the systems

This data is collected to help make decisions as to what sorts of systems work best for plants, and how they can be integrated together, and to aid in determining if there are issues with certain things being put together due to size or some other constraints. Additionally this may reveal if some systems are more difficult to maintain individually, apart from another, or combined with others.

4. Environment

This is the area outside the greenhouse and where it's located.

The following will be collected in this study;

- Surrounding area
    - Quality of the area

    - Aspects of interest - such as being next to a building, or trees

This will be collected to help determine what sort of environmental objects impact the flow and quality of the growing process. For instance, if there is a lot of foot traffic around the greenhouse, does that contribute to people visiting or doing damage to it. Are these factors impacting the systems that are used that can be taken into consideration that may have been overlooked.

5. Other Areas of Interest

This broadly includes anything that doesn't fit the above four components, yet would be something that could potentially impact the greenhouse. Giving specifics of this is difficult as they are largely unknown, but a few examples would be as follows.

- promotional material that's located outside and away from the greenhouse;
- something related to an educational program in the greenhouse;
- If music is being used to help grow plants.

This would give insight and potentially act as a reminder that there are things outside our control that have impacts.

Appendix C: Consent Form

Worcester Polytechnic Institute ’19 IQP

Greenhouse Optimization

Consent to take part in research

Research Explanation and Objective: Optimization of a greenhouse with an education plan to address food insecurity on college campuses. Research is directed towards materials, systems used, logistics, plants, education components, & insight into (un)successful practices.

- I…… voluntarily agree to participate in this research study.
- I understand that even if I agree to participate now, I can withdraw at any time or refuse to answer any question without any consequences of any kind.
- I understand that I can withdraw permission to use data from my interview within two weeks after the interview, in which case the material will be deleted.
- I have had the purpose and nature of the study explained to me in writing and I have had the opportunity to ask questions about the study.
- I understand that participation involves answering questions and explaining details about the greenhouse located on site, regarding operations, optimization, education, and food insecurity.
- I understand that I will not benefit directly from participating in this research.
- I agree to my interview being audio-recorded.

- I understand that all information I provide for this study will be treated confidentially and not used for profit.
- I understand that in any report on the results of this research my identity will remain anonymous. This will be done by changing my name and disguising any details of my interview which may reveal my identity or the identity of people I speak about.
- I understand that disguised extracts from my interview may be quoted in a project report and project presentation.
- I understand that signed consent forms and original audio recordings will be retained on a Google Drive which only the team of the project has access to until August 20th, 2019.
- I understand that a transcript of my interview in which all identifying information has been removed will be retained until August 20th, 2019.
- I understand that under freedom of information legalisation I am entitled to access the information I have provided at any time while it is in storage as specified above.
- I understand that I am free to contact any of the people involved in the research to seek further clarification and information.

Names, degrees, affiliations and contact details of researchers (and academic supervisors when relevant).

Signature of research participant

---------- ----------

Signature of participant Date

Appendix D: Photo/Information Release Form

Worcester Polytechnic Institute ’19 IQP

Greenhouse Optimization

Photo/Information Release Form

Print Name:_____ Signature:_____

Address:_____ Phone:_____ Email: _____

I AGREE TO have pictures taken (whether in 35mm film, electronic digital, electronic video, or other format) in, about, and around the greenhouse located on the address on the bottom section of this form.

In addition, I hereby **give** the representative below the **exclusive right/my permission** to reproduce and use the photos solely for the purpose of the project.

Photo session greenhouse location

_____

_____

Today's date_____

Appendix E: Across Lists

Across 4

Optimization

Materials/Equipment

- Watering Systems (manual)
- Shelves/Table

Organization

- Storage Space (some not proper)

Safety

- Lock Doors

Types of education

Training Staff/Volunteers

- Training

Experiments

- Education of people of all ages
    - REC Youth Grow (2,3)
    - Mentoring Students (1)
    - Chandler Magnet (4)

Community Awareness

- Community Outreach

- QCC - PTK
- REC and/or club (2,3,4)

Across 3

Optimization

Structures

- Special Glass (1,2,3)

Materials/Equipment

- Peat Moss (1, 2, 3)
- Artificial Light (1,2,3) *only really utilized in 1*
- Thermometer (1,2,3)
- Heating system (1,2,3)

Automation

- Watering system Automated (1,2,3)
- Automated heating system (1, 2, 3)

Plants

- Healthy Plants Inside (1,2,3)

Records

- Limited or no access to records, if at all available (2,3,4)

Safety

- Key holder log (1,2,3)

Types of eduction

Training Staff/Volunteers

- Training / teaching - outside group (2,3,4)
- Extra curricular classes - by GH (1,2,4)
    - QCC occasionally
    - WPI - Plant Parenthood
    - WSU - Teaching Garden

Community Awareness

- GH Fliers (1,2,4)

Across 2

Optimization

Structures

- Large area greenhouse (2,3)
    - Comfortable spacing, improved work area; table set up.
- Drain in floor (2,3)
- Modifiable - removeable (2,3)

Materials/Equipment

- Automatic/Manual Windows (2,3)
- Ventilation Fan (2,3)
- Tubs - for potted plants (2,3)

Plants

- Hanging bar for plants (1,2)
- Grow plants outside when in season (1, 4)
- Grows food and non-food plants (1,4)
- Grows only non-food (2,3)

Environment

- GH is connected to academic facility, on roof (2,3) *too much sun for 2*

Sustainability

- Compost (1, 4)
    - Worm Farm (1)
    - Plant matter (4)
- Reusing water (2,4)

Records

- Built with Grant (1,3)

Safety

- Security Camera (1,2)

Types of education

Experiments

- Classes / Experiments - by school (2,3)

Community Awareness

- Grow plants outside - for awareness (1, 4)
- Logo and Greenhouse Name (1,4)
- Researched into Food Insecurity of students, and raising awareness (1,4)

Food Insecurity

- Food Pantry (1,4)
- SNAP/WIC (1,4)

Across 1

Optimization

Structures

- Each facility is set up differently, due to size/shape;
    - Case 1 had 1 room, and a rectangular shape
    - Case 2 had 4 rooms, and square shapes
    - Case 3 had 2 rooms and a rectangular shape
    - Case 4 was one big open area, and a more free flowing shape
- Small Structure (1)
    - Cramped spaces, decrease mobility
- Compost Section (4)
- Hoop House (4)
    - Could be set up without having the tarp on the top.
- ADA Compliant (4)

Materials/Equipment

- Net (1)
- Plant Spray (1)
- Water Filtration (1)

- Automatic Vent - no fan(1)
- Worm Farm casing (1)
    - Tomato experiment
- Hanging Fan (2)
- Alarm for temp - too hot (2)
- Swamp-Cooler (3)
- Chair (3) - mobility
- Shade Cloth (3)
- Ergonomic Rake tool (4)
- V-Troth (4)
- Compost container (4)
- Garden Supplies (4)

<u>Plants</u>

- Height sticks (1)
- Unhealthy plants outside (1)
- Certain plants grown together for specific reason (1)
- Non-GMO Organic Seeds (1)
- Unhealthy plants inside (3)
- Healthy Plants outside (4)

<u>Environment</u>

- On ground Located next to building - blocking sun (1)
- Natural pest control - dragon flies(4)

- Natural pollination - bees (4)

Sustainability

- Recycled Devices (4)

Records

- Food log (1)
- Fundraising (1)
- Work task (1)

Safety

- Sprinklers (3)
- Fire Extinguisher (3)

Types of Education

Training staff/volunteers

- Troubleshooting Guide (2)

Community Awareness

- Plant Parenthood (2)
- Waive Fees for Basic Gardening Course (4)

Food Insecurity

*All colleges had some form of food insecurity

Appendix F: Component Checklist

Check list of components found across all cases and an Ideal Case

Optimization	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Ideal Case**
Structure					
Special Glass	X	X	X		X
Large Area		X	X	X	X
Multiple Rooms		X	X		X
Floor Drain		X	X		X
Modifiable		X	X		X
Compost Area				X	X
ADA Compliance				X	X
Material/Equipment					
Shelves/tables	X	X	X	X	X
Watering tools	X	X	X	X	X
Sediment Sink Traps					X
Artificial Lighting	X	X	X		X
Thermometer	X	X	X		X
Heating System	X	X	X		X
Peat moss dirt	X	X	X		X
Openable Windows		X	X		X
Ventilation Fan	X	X	X		X
Plant Tubs		X	X		X
Plant Spray	X				X
Water Filtration	X				X
Hanging Bar	X	X			X
Hanging Fan		X			X
Temperature Alarm		X			X
Chair			X		X
Shade Cloth			X		X
Ergonomic Tools				X	X
V-Troth				X	X
Plant Measuring Sticks	X				X

Automation					
Watering System	X	X	X		X
Lighting System					X
Heating System					X
Cooling System					X
Window System		X	X		X
Plants					
Food	X			X	X
Non-Food only		X	X		
Inside Growing	X	X	X		X
Outside Growing	X			X	X
Non-GMO Organic Seeds	X				X
Plants grown together	X				X
Environment					
Connected To Building		X	X		
On Roof		X	X		
On Ground	X			X	X
Natural Pest Control (bugs)				X	X
Natural Pollination				X	X
Sustainability					
Plant Composting				X	X
Worm Farm	X				X
Reusing Water		X		X	X
Recycling Materials				X	X
Renewable Energy					X
Organization					
Storage Space	X	X	X	X	X
Records					
Access to Facility Records	X				X
Financial Records	X				X
Food Log	X				X
Work Tasks	X				X
Fundraising	X				X
Safety					
Sprinklers			X		X
Fire Extinguisher			X		X

Security Cameras	X	X			X
Lockable Doors	X	X	X	X	X
Keyholder Log	X	X	X		X
Training					
Train Staff/Volunteers	X	X	X	X	X
Teaching (outside groups)		X	X	X	X
Classes by Facility	X	X		X	X
Troubleshooting Guide		X			X
Experiment					
Class experiments		X	X		X
Education for all ages	X	X	X	X	X
Community Awareness					
Community Outreach	X	X	X	X	X
Facility Fliers	X	X		X	X
Outdoor Plants	X			X	X
Logo and Facility Name	X			X	X
Research into Food Insecurity	X			X	X
Facility based Club		X			X
Fee Waiver for Gardening Course				X	X

Food Insecurity

Food Pantry	X			X	X
SNAP/WIC connection	X			X	X