# Final Report A01

**GNG1103 - Engineering Design**

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## Abstract

This technical document outlines all the work completed by GNG1103_A01 on their course project; Hydroponic system. It begins with an introduction and takes you through the experience that students went through while creating their hydroponic system. They contacted a client and learned the issue in more depth to understand and state the problem. Early concepts of the system were created to grasp an idea of what will be made come the end of the term. Scheduling and Cost of the Design was done next to organize themselves appropriately for the semester. Three prototypes were made before presenting to the class and learning lessons for the future and concluding.

## Introduction

Our project design team were tasked to design a hydroponic system given client appeal for the course GNG1103 Engineering Design. A design thinking strategy outlined as five general steps helped guide our team in presenting a final working prototype, which was then demonstrated to the public.

An initial meeting was held with a client, who used to reside as a Syrian refugee in a Jordanian refugee camp. The refugee provided us with valuable suggestions about how to design a solution to satisfy the conditions in a refugee camp. The empathizing procedures, presented in weekly lectures, helped set the direction of how our team generate a design criteria and solution.

At weekly team meetings, several concepts were drawn and introduced, and the best key concepts were integrated and combined to compile our team's hydroponic system final design. A schedule of tasks was made on Microsoft Project, followed by a Bill of Materials which kick started our team's prototyping stage.

Our team built 3 prototypes overall, each with their own testing objective, and unique designs. Prototype I was simple and mainly used for communicative purposes. Prototype II was focused on the main sub-system in the overall solution to ensure there were no surprises come the final prototype. Prototype III was a comprehensive prototype which was built with purchased materials and characterized multiple attributes of the final solution.

Final lessons were covered to describe what we learned after presenting our system to multiple audiences, and what we plan to do in the future based off those lessons.

## Client meeting

On January 23rd, our refugee client conveyed how refugees that are fleeing Syria, survived in rough desert conditions of refugee camps. Hearing it first hand from a refugee tell his story gave us an opportunity to express empathy, leading to the following notes that were gathered:

- Lack of natural water sources: Water is trucked in by the Government of Jordan.
- Extreme temperature conditions: (40℃ to -1℃)
- Absence of any electrical infrastructure: Could not implement solar or renewable energy.
- System should be easy for any refugee with any education level to use
- Any structure must survive rough winter rainfalls, severe floods.

It was necessary to convert the given design description into a Needs Statement, because at the time, our team did not have a clear defined direction to start designing a hydroponic system. To further learn about the situation in the refugee camps we also did our own research on the Zaatari refugee camp. [9]

## Problem Statement

The Problem Statement was expanded into a table which prioritized the importance of each statement, that helped clarify the real problem we needed to solve. Some assumptions were made along the way as we did not have a way of physically empathizing with the client. We

believe our assumptions were made within the possibility and scope of the experiences refugees go through.

### Problem Statement Quote

*"A need exists for refugees to produce their own food with the use of a hydroponic system that is cost efficient, low on water consumption, user-friendly, durable and able to operate despite the lack of electricity. "*

**Table 1. Needs Statement with Importance Ranking**

| No. | Need Statements | Importance Rank (5-Highest, 1-Lowest) |
|---|---|---|
| 1 | The refugees are able to grow crops without using much water. | 5 |
| 2 | The refugees are able to afford the solution. | 5 |
| 3 | The system functions without electricity. | 5 |
| 4 | The system is able to function in the desert/arid conditions. | 4 |
| 5 | The system is able to withstand varying temperatures. ( 40℃ to 0℃ ) | 4 |
| 6 | The system requires low maintenance. | 3 |
| 7 | The system is easy to operate. | 2 |
| 8 | The system is able to withstand sinking sand during rainfalls. | 1 |

Having established what our design team will focus when designing, our team compiled a table that helped sets the benchmark of how we will determine if our design is 'the best solution'.

**Table 2. Design Metrics and Units**

| ***Metric #*** | ***Need #*** | ***Metric*** | ***Importance*** | ***Units*** |
|---|---|---|---|---|
| 1 | 1 | Usage of water | 5 | Litres(L) |
| 2 | 2 | Cost | 5 | CAD ($) |
| 3 | 3 | Usage of electricity | 5 | Watts(W) |
| 4 | 4 | Functional in desert/arid regions | 4 | Yes/No |

| | | | | |
|---|---|---|---|---|
| 5 | 5 | Temperature range (The system can work) | 4 | (℃) |
| 6 | 6 | Maintenance | 3 | High/Low |
| 7 | 7 | Complexity in operation | 2 | High/Low |
| 8 | 8 | Functional in rainy season | 1 | Yes/No |
| 9 | 9 | Growth Area | 3 | ($m^2$) |

By researching several varying options available in the market today, it helped our team gauge the market specifications were, and how we should not only base our design, but also improve and design a competitive product. Our research led to three on the market hydroponic products.

## Benchmarking Matrix

**Table 3. Benchmarking Table using 3 On-the-market products [6][7][8]**

| **Metric#** | **Need#** | **Metric** | HTG Organic 600W Grow Kit | Mylar Hydro Shanty Hydroponic Indoor Grow Tent | Hydro Home Grow-Room Tent |
|---|---|---|---|---|---|
| **1** | **1** | **Usage of Water** | n/a | n/a | n/a |
| **2** | **2** | **Cost** | $449.00 | $219.00 | $339.01 |
| **3** | **3** | **Usage of Electricity** | 600 Watts | 400W - 600W | 100-200W |
| **4** | **4** | **Functional in Desert/Arid Regions** | n/a | No | Yes |
| **5** | **5** | **Temperature Range (The system can will function)** | n/a | n/a | n/a |
| **6** | **6** | **Maintenance** | Low | Low | Low |
| **7** | **7** | **Complexity in Operation (Systems)** | Medium | Medium | Low |
| **8** | **8** | **Functional in Rainy Season** | Yes | Yes | Yes |

| | | | | | |
|---|---|---|---|---|---|
| **9** | **9** | **Growth Area** | 1.5 cubic feet pot | 1.9 x 1.9 meter | 2’ x 4.3’ feet tent |

Researching for further details were difficult, because all three manufactures do not have any comprehensive technical specification document that list any of the crucial metrics that our team had determined. Nevertheless, the information we could gather helped structure our target specifications appropriately, such as: plant growth volume, current attempts and design implementations, material necessary to construct a whole enclosed hydroponic system.

The most important factors that stood out to us was that these systems required some degree of electricity, even at higher price points. Running on as little electricity possible was one of the primary design criteria that we prioritized, and having seen that most products available currently use electricity to a great degree, meant that it was difficult to design hydroponic systems without the use of electricity. We also noticed that there were currently no company that attempts to solve this refugee problem, which provided our team with hope that what we are designing in the class, will be of great benefit in serving refugees.

With the information provided, and processing it through the empathizing procedures taught in class, our team could develop a Needs Statement that defines what problem our team is aiming to solve, a design matrix, and benchmarking matrix that helped our team define an appropriate solution that we were to design towards.

## Conceptual generation

Moving onto the next stage in designing a hydroponic system, our team needed to brainstorm ideas on what kind of system design will satisfy the needs statement and become a solution. Free-hand sketches proved to be the most efficient way to generating large amounts of ideas, and it became easy for us to substitute and even integrate several designs together.

### Global design

Our integrated solution combined differing designs generated by each team member that were compatible with each other, though was adapted and changed over the remaining period until the Final Prototype III. To explain our initial concept, we have included this sketch.

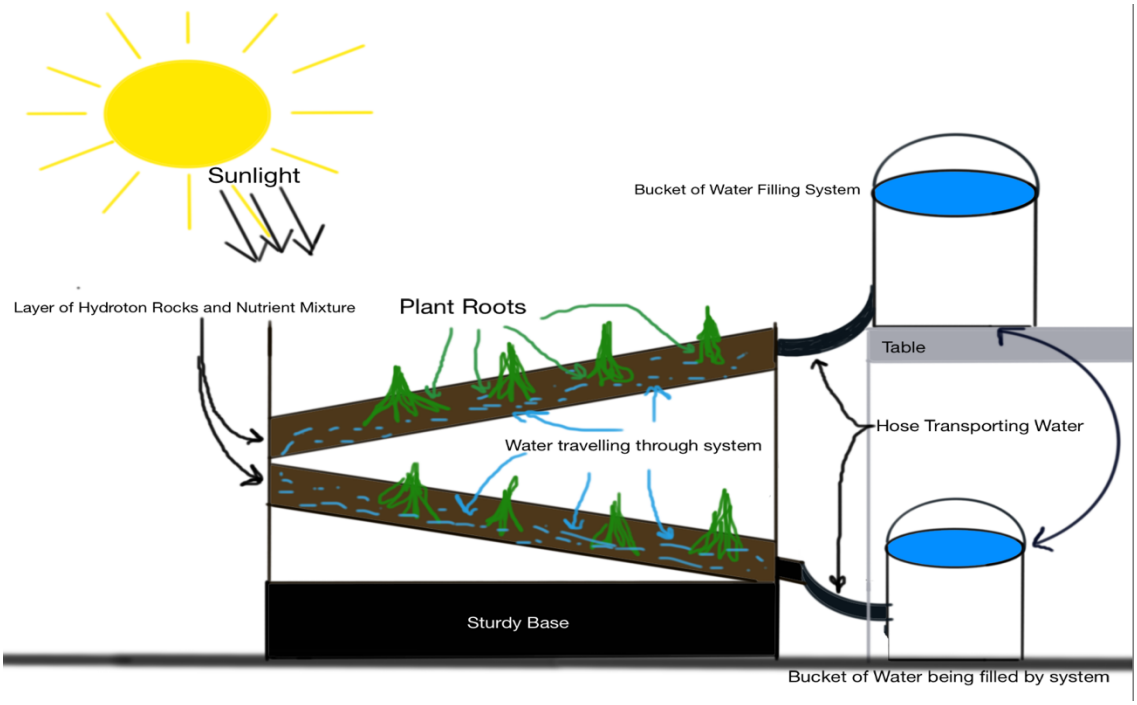



**Figure 1. Drawing of A01 integrated initial design**

## Four key design concepts

- Gravitationally move greywater, that were (from showering center) processed through filters and combined with nutrients to supplement all plants, down along a ramp. [2]
- Store water in standardized containers such as water jugs, or buckets with lids that refugees have access to.
- Control water flow with the use of taps, optimizing the flow rate such that water does not drain completely from the top reservoir.

## Other concepts

The following is a brief list of other plausible implementations/designs that were generated during our brainstorming sessions include:

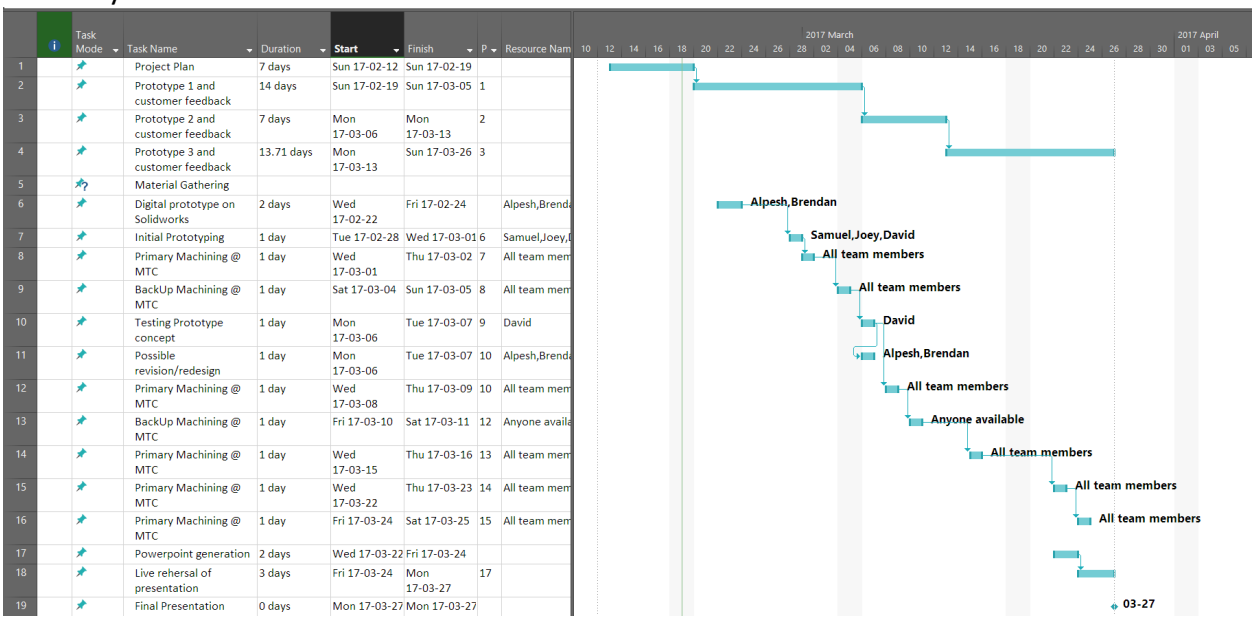
- Absorbent materials such as fabrics to transport water through the system water molecule's surface attraction. [3]
- Hydroton rocks as a growing medium, made from clay-like material, that allows a plant to sprout its roots within, and absorb nutrients and water through the medium.
- Wick, created from simple and abundant materials that can be soaked in water and slowly absorbed by the plant. [4]
- Pulley of buckets to rotate the reservoirs whenever the bottom reservoir is filled with water, drained from the top reservoir.
- Burying pots of plants underground to withstand the ambient desert condition. [5]

## Scheduling and Cost of Design

Once we knew what design our team wanted to build, we began planning the execution of building the hydroponics system. This included scheduling meeting times as well as deadlines to finish deliverables and build the prototypes of the system. This also included calculating the estimated cost of all the prototypes.

### Scheduling

To design and build an effective hydroponics system, making a schedule is crucial. It allows for more efficient time usage and make it easier to reach goals by deadlines. We organized our time by creating a gantt chart to outline all the deadlines and to set times that we plan to work on the system.



| | Task Mode | Task Name | Duration | Start | Finish | P | Resource Nam |
|---|---|---|---|---|---|---|---|
| 1 | | Project Plan | 7 days | Sun 17-02-12 | Sun 17-02-19 | | |
| 2 | | Prototype 1 and customer feedback | 14 days | Sun 17-02-19 | Sun 17-03-05 | 1 | |
| 3 | | Prototype 2 and customer feedback | 7 days | Mon 17-03-06 | Mon 17-03-13 | 2 | |
| 4 | | Prototype 3 and customer feedback | 13.71 days | Mon 17-03-13 | Sun 17-03-26 | 3 | |
| 5 | | Material Gathering | | | | | |
| 6 | | Digital prototype on Solidworks | 2 days | Wed 17-02-22 | Fri 17-02-24 | | Alpesh,Brend |
| 7 | | Initial Prototyping | 1 day | Tue 17-02-28 | Wed 17-03-01 | 6 | Samuel,Joey,I |
| 8 | | Primary Machining @ MTC | 1 day | Wed 17-03-01 | Thu 17-03-02 | 7 | All team mem |
| 9 | | BackUp Machining @ MTC | 1 day | Sat 17-03-04 | Sun 17-03-05 | 8 | All team mem |
| 10 | | Testing Prototype concept | 1 day | Mon 17-03-06 | Tue 17-03-07 | 9 | David |
| 11 | | Possible revision/redesign | 1 day | Mon 17-03-06 | Tue 17-03-07 | 10 | Alpesh,Brend |
| 12 | | Primary Machining @ MTC | 1 day | Wed 17-03-08 | Thu 17-03-09 | 10 | All team mem |
| 13 | | BackUp Machining @ MTC | 1 day | Fri 17-03-10 | Sat 17-03-11 | 12 | Anyone availa |
| 14 | | Primary Machining @ MTC | 1 day | Wed 17-03-15 | Thu 17-03-16 | 13 | All team mem |
| 15 | | Primary Machining @ MTC | 1 day | Wed 17-03-22 | Thu 17-03-23 | 14 | All team mem |
| 16 | | Primary Machining @ MTC | 1 day | Fri 17-03-24 | Sat 17-03-25 | 15 | All team mem |
| 17 | | Powerpoint generation | 2 days | Wed 17-03-22 | Fri 17-03-24 | | |
| 18 | | Live rehersal of presentation | 3 days | Fri 17-03-24 | Mon 17-03-27 | 17 | |
| 19 | | Final Presentation | 0 days | Mon 17-03-27 | Mon 17-03-27 | | |



**Figure 2. Project Plan created using Microsoft Project (Gantt Chart)**

### Cost of Design

Before we began building the hydroponics system, we needed to estimate a cost of the whole system. This would allow us to better understand the limits of our budget and purchase materials accordingly.

#### Cost for Prototype One

Our first prototype was built out of scrap material and as such did not cost anything.

#### Cost for Prototype Two

Our second prototype was also built out of scrap material which means we did not need to use any of our budget until the final prototype.

### Estimated Cost of Final Prototype

When planning what materials to purchase, we estimated a cost of about $80. The items we planned to use were all taken from Amazon. However, once the building process was about to begin, we decided to change a lot of the materials we planned to use.

**Table 4. Estimated Cost of Final Prototype**

| | | |
|---|---|---|
| System Container | 81-gallon airtight container | $20 |
| Bucket | 5L bucket with lid | $10 x 2 = $20 |
| Water Tubing | Aquarium Tubing | $8 |
| Hydrotonics | Rocks, Coco coir croutons | $17 |
| Plant holder | Plastic Net | $7 |
| Slanted Platform | Wood with waterproof coating | Should be able to obtain for free |
| Glue | Epoxy Glue | $8 |

### Actual Cost of Final Design

With further evaluation of our available resources, discovered that there was much better resource we could use that did not come from Amazon. Due to our material change, we could build the system with less than $30.

## Prototyping

After compiling a list of materials that our team needed, started building focused prototypes of our solution. Building a focused prototype allowed our team to validate the fidelity of each key concept, and helped our team detect possible failure modes. Any potential problem that was brought up could be immediately worked upon.

### Making Prototype I

The test objective for Prototype I was to determine the overall build of the prototype, and communicating our design solution, via a physical model, to our client. We started by making a miniature model of the designed hydroponic system out of the basic household items such as cereal boxes, popsicle sticks and hot glue. We used the cereal boxes to model the outer walls of our hydroponic enclosure, and we made a ramp that we modeled to demonstrate how water will flow through the system. At this point we had determined we will need to test the height of the ramp such that water doesn't completely drain too quickly on our future prototypes. Since

this prototype was mainly used for communication, it was also a learning tool for our group to determine how we would continue to the next prototypes as well.

### Feedback from Client

- Concerned about sinking land and tilting the solution after we brought up that we heard there is land movement during the heavy rainfalls
- Concerned about how often they will have to check up on the system in terms of maintenance and water supply since system seems to have a rapid process
- Likes the simplicity of the concept and how it does not require any electricity
- Questioned material to be used but was pleased to hear it would be of cheap materials that are easily accessible

**Figure 3. Prototype I**

### Making Prototype II

The test objective for prototype II was to display one of our main functionalities/subsystems which we only displayed but not demonstrated in prototype I. The subsystem that's being created in this prototype is the flow of water throughout the system without the use of electricity (pump) and will be looked at from a focused/physical prototype point of view. The reason that we have decided to go with a focused/physical prototype type is because our client showed interest in how the device would function without electricity. After consulting with our client and research, we concluded that access to electricity in the refugee camp is extremely difficult since an expensive battery must first be purchased, and it must also be recharged every night. We concluded that the most cost-friendly way of getting our system to function in this aspect is by using gravity, which will be the centerpiece of this prototype.

The procedure to creating and testing the prototype is by first creating a ramp to simulate the base of where the water will flow. We created the ramp out of two thick sheets of cardboard which we glued together using hot glue. We then lined the ramp with thin plastic to prevent the cardboard from becoming soaked. We decided to make two channels for water flow on the ramp. We separated the two channels using cardboard slabs. We then cut two holes into both channels which we placed cups into to simulate the plant holders

The height at which the ramp is at will also be analyzed with the actual flow of water to ensure that the system performs as required.

**Table 5. Timing Data for Heights of Prototype II**

| Heights(cm) | Control (Without any holes) (s) | Cups filled with wood chips(s) |
|---|---|---|
| 6 | 15.46 | 38.17 |
| 11 | 13.74 | 35.32 |
| 22 | 9.91 | 25.95 |

As the results show, the lower height meant a longer amount of time for all the water to drain from the top reservoir to the bottom of the system. Therefore, to be as water-efficient as possible we want our height to be the lowest possible yet still allow water to travel into the appropriate cups and saturate the soil.

### Feedback from Customer

- Approves and very pleased with how the system is going to use gravity for the water flow rather than an electric powered pump
- Glad about how the initial prototype was an accurate communicating tool as a follow up to prototype 2 where he could now observe the function
- Concerned about how often the buckets will have to be switched after the water has transferred from the top bucket to the bottom one
- Concerned about how sturdy the system's ramp will be so that slight movements won't hamper the flow of water
- Concerned about the amount of water needed for the system to function constantly
- Concerned about the amount of room given for the plants to grow

After the initial prototype, the team was excited and eager to create a functional system which had a function. Assessing some factors from prototype I allowed us to create prototype II in a smooth, chronological manner. Our customer was pleased with what he saw but still needed some clarification as the prototype was once again made of household materials. Fortunately, this prototype did not cost us anything. We used materials such as hot glue, popsicle sticks and string which were leftover materials from the last prototype. The other materials that were used such as the cardboard, plastic and cups were all found and not purchased. We realized and learned after this prototype what our client was worried about and what he really wanted in a final product. The complication that we encountered was that the channels of water were wider than the cups we were trying to direct them into, but to overcome it in the end we figured we could narrow the channels to fit the direct width of the cup or add barriers to direct the flow. As for stopping criteria for this prototype, we decided that once we found an optimal height for the most efficient flow of water we would be satisfied. By multiple testing as shown

in the table above, we could conclude with reliable results that the optimal height ranges from 6 cm to 11 cm.

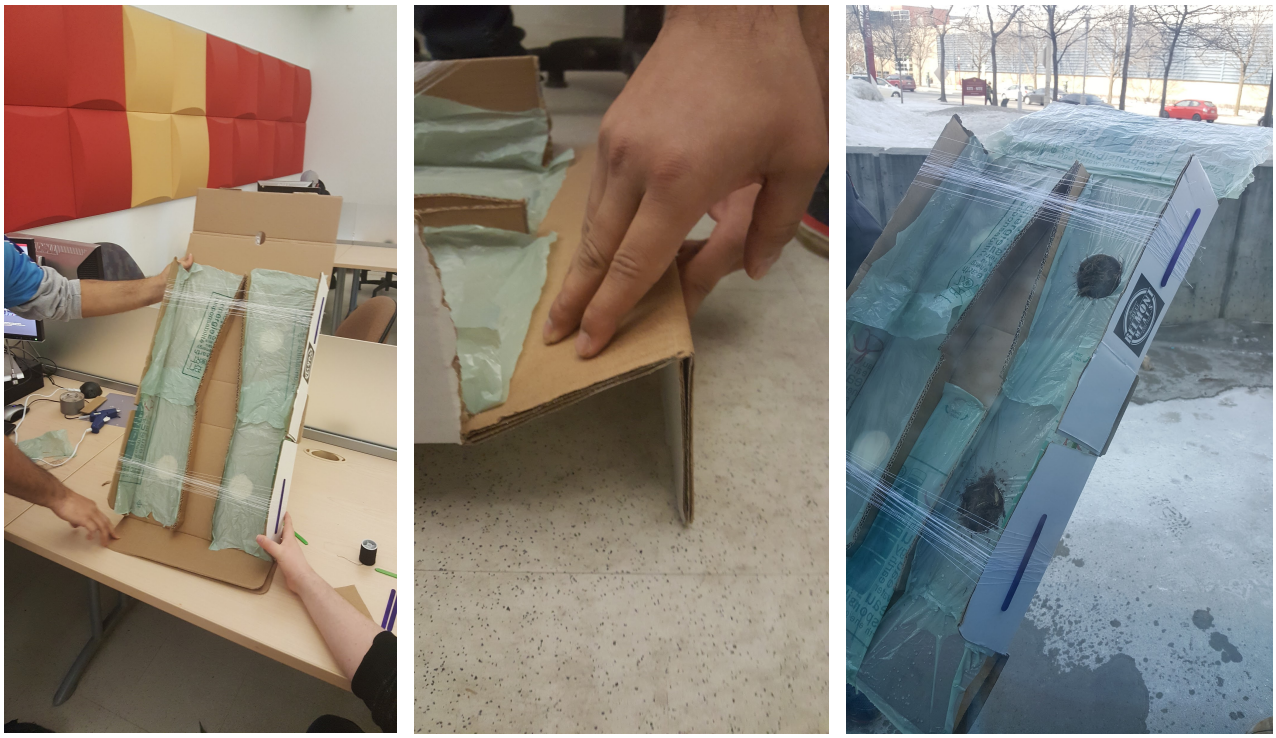


**Figure 4. Construction of Prototype II (left), How to adjust height (middle), Real testing (right)**

### Making Prototype III

The test objective for prototype III was to create a comprehensive, and physical type that was also a functional version of our system. This prototype is also a continuation of prototype I and II; since we made the necessary changes and took feedback to further provide a system that both our client and group would be satisfied with. The functionalities we wanted to implement in this prototype was the flow of water through our implemented tubing system, the correct ramp height for optimal water distribution, the cup sections where the plant and soil will be held, a twist-valve to control the amount of water from the top reservoir released, and a shelf to hold the top reservoir. This is also why we went with a comprehensive/physical type, because we had many features on our final product being implemented here. A big feat for us was getting the entire system to function with the addition of multiple changes we made to accommodate to our clients' feedback.

After consulting with our client from the previous two prototypes and since this was the last prototype, we decided that the prototype needs to be built as close to our final solution as possible. This way we can demonstrate the prototype to our client and almost exactly how it would be used at the refugee camp.

The procedure to creating and testing the prototype started by building the frame from Lees campus workshop and materials. The materials required are wood sheets, one large sealed

containers, plastic tubing, nails, wood glue, sand, hot glue and sheets of tarp. The cost of the prototype was approximately CAD $50 considering all the minimal input such as hot glue. Being built from scrap wood, we needed to test its ability to retain water in the enclosure. We have lined the insides with a single continuous piece of tarp to decrease the likeliness of water leaking. The tubing was also routed from the top water reservoir through a tap and into a secondary tube with holes that match the channel stream. By rotating the tap, we could control the flow of water that saturates the plants.

The measurements that were made was the amount of time for water to saturate all cups of soil, and the angle rotated on the tap to give the ideal amount of water flow.

**Table 6. Angle of Tap and Time to Fill Cup with Water**

| Angle of Tap ($^{o}$) | Time for cups to saturate fully (min) |
|---|---|
| 60 | 63 |
| 75 | 37 |
| 90 | 25 |

We found that with the tap turned to open at 60$^{o}$ it took the longest amount of time from the tests that we made, with the sealing angle at 45$^{o}$. Therefore, with further testing we would be able to test at an angle smaller than 60$^{o}$ but greater than 45$^{o}$ which would fit our final solution more. The size of the cups is another factor to take into mind as these were just small Tim Hortons cups.

### Feedback from Customer

- Approves and extremely happy with how the final system incorporates all the previous sub-systems shown
- Overjoyed with how simple the prototype will be able to operate for any refugee in the refugee camps
- Happy with the mechanics for the system to function
- Happy with the little amount of maintenance needed
- Concerned with amount of water needed for various plants
- Slightly concerned with sizing
- Slightly concerned with sturdiness of base since it may be on unsteady grounds during rainfalls

After completing prototype II, we took time in our schedules to meet up and decide the design ideas which would give us and our client full satisfaction for the next step. The team was excited to finally put our budget to use to create a final comprehensive prototype that we could all be proud of, including our client. The overall system cost about $50 CAD, with the materials being obtained from Lees workshops and Home Depot. Building the system took time since we had to calculate correct dimensions so that we could properly adjust the materials we were given to work with. Some dimensions were slightly off during the construction of the system

but not significant enough to change the overall result of the system. Our stopping criteria was to have the multiple attributes properly functioning in this prototype and record a proper tap angle for the optimal flow of water to the correct cups. After displaying our final prototype to our customer, we can confidently say that he was very pleased with the system and was only concerned with easily solved issues that would be covered in the final completed product. The learning experience for us is that it is best for both parties to stay in constant contact to find the best solution to help the whole of the Syrian refugees.

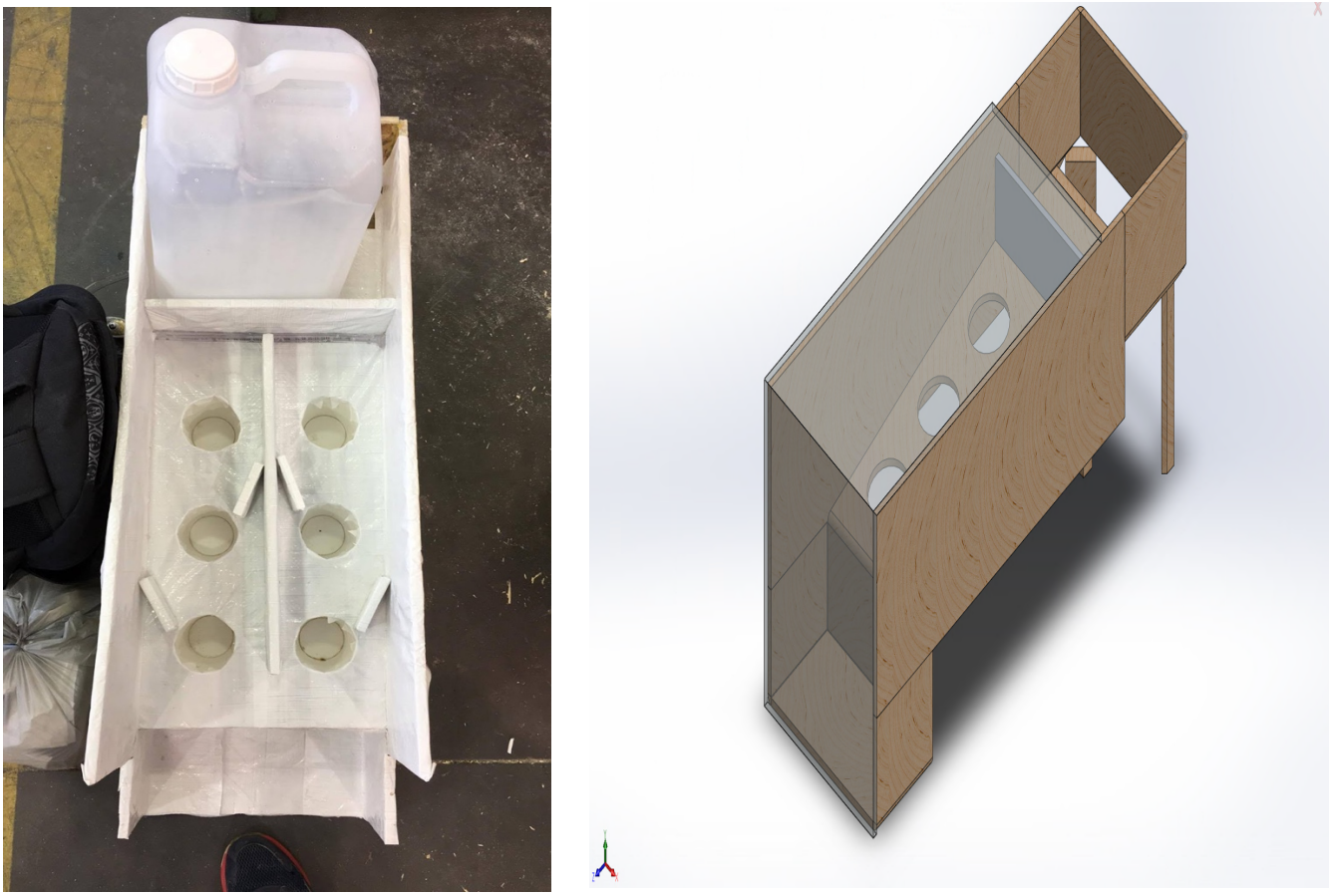


**Figure 5. Actual completed prototype III (left), Solidworks Prototype III (right)**

## Final Lessons

### Advantages

1. Our system costs approximately CAD $50, which was our target specification and we can produce this system with such a low price.
2. There is no need of electricity to run this hydroponic system, thus saving the refugees the hassle for more energy to be used just to acquire food.

3. The mechanism of this system is quite simple and easy to understand for both educated and uneducated refugees in the camp. (Details of functioning explained above) Hence, suitable for every refugee in the camp without any panic if things do not work well with the system.
4. Moreover, the parts needed for maintenance are available locally in Jordan through companies such as FLAMCO[1] having retailers in Jordan.

### Disadvantages

1. The growth area in the system does not receive water equally, rather some areas receives more than the other. (current prototype)
2. The system is not quite steady as per current design, it is not suitable in the sinking sands of the desert during rainy season. (current prototype)
3. The water channeling strategy is not adequate as per tests done on the prototype and needs a revamp for efficiency. (current prototype)
4. There is no cover on the current design which is not acceptable given the harsh conditions in the desert which might evaporate the water. (current prototype)

### Design Day Feedback

For the most part, the feedback that we got back, was that our design was good, however, there were a few concerns that people had with our design. Most of these concerns had to do with the consistence. Since our system relied on pressure to transport water, the pressure felt at each hole would decrease as the holes went down the tube. This means that less and less water would get to plants that are further along the tube (the leftmost tube would give the most amount of water, which the rightmost tube would get the least). While the difference in water was noticeable during testing, it may have an impact on how fast the plants grow, making certain plants grow at certain rates. The solution that we have already proposed to this is that we add a second tube coming in from the other side as well so that both sides would get equal water pressure. This may not completely fix the issue but it would increase the consistency throughout the system. Another solution we have thought of is that the plants are simply switched or we create removable pots in our system so that they are easily interchangeable.

### Future Implementations

Although the final prototype has been completed we still have future implementations we would like to do. We want to work on enclosing the system with an acrylic casing to help with evaporation but still provide sunlight to the plants. Another feature is to include a steady base at the bottom to prevent sinking during rainy seasons. The surface area for plant growth is not very large and we wish to expand that in an overall larger system. Finally, since the water distribution isn't ideal as we learned from design day, we want to test our idea with channeling from both side of the system to equalize the water pressure, and create a way to have interchangeable pots to change plants around for more even distribution of nutrients.

## Conclusion

Our current hydroponic system is ready to use barring the slight touches which need to be covered for efficiency and reliability in terms of pH and nutrients. Overall, we would like to encourage any potential sponsors and donations to further improve our final product potentials and give an even more complete product to our potential customers. The aim has always been customer satisfaction from day one on this project. As we uphold what the customer wants and what is needed, rather than our profits.

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