# The Four Tall Redwoods
## Starter Box Greenhouse

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# 1. Problem Formulation

## 1.1. Introduction

In section 1 the Four Tall Redwoods announce their objective statement as well as illustrate a simplified version of the design process using the black box model.

## 1.2. Objective

The objective is to design and construct a Mobile Greenhouse to help educate 7th grade students on the plant life cycle as well as help them gain an understanding of how a greenhouse works to provide the necessary components, such as sunlight, to a plant for growth. The Black Box model shown in Figure 1.1 describes the inputs and outputs of our design.


Figure 1-1 Black Box Model

# 2. Problem Analysis and Literature Review

## 2.1. Problem Analysis

### 2.1.1. Introduction

The problem analysis identifies the possible input and output variables, along with their respective constraints. It describes the project specification, considerations, production volume, and usage.

### 2.1.2. Specifications

The specifications for this design project is to have a usable long-term mobile greenhouse that will allow seventh grade students to easily access their plant projects in a Dixie cup. Table 2.1.2. below is an outline of the design specifications.

Table 2-1 Analysis of Specifications

| Specification | |
|---|---|
| Size | Must fit through classroom doorway |
| Mobility | Capable of transporting experiments |

### 2.1.3. Production Volume

For this design project, only one prototype will be made and tested.

### 2.1.4. Usage

The mobile greenhouse must be capable of being wheeled in and out of the classroom every day. It must house 150 plants and be easily accessible to students. It will be used seasonally but designed to withstand year-round use.

### 2.1.5. Considerations

There are many considerations involved in this project, mostly those concerning student safety and plant accessibility. The materials utilized in the construction of the cart must be safe and durable in order to withstand student handling, considering that student handling may not be the gentlest when handling the greenhouse. Considering students of the ages 12-13 may not be capable of moving heavy objects, the cart must be of an appropriate weight to be moved and be stable enough to withstand tipping. Overall plant health and well-being must also be considered. Table 2-2 below outlines the design criteria and constraints.

Table 2-2 Analysis of Criteria and Constraints

| Criteria | |
|---|---|
| Safety | Design must be safe for students to use |
| Cost | Total must be less than $200 |
| Size | Minimizes classroom space used |
| Maneuverability | Easily moves about classroom<br>Practical accessibility to experiments |
| Durability | Requires minimal routine maintenance<br>Durable enough to endure seasonal use |

## 2.2. Literature Review

### 2.2.1. Introduction

In section 2 we introduce our Literature Review. Our Literature Review includes information about our client's design criteria followed by basic plant needs, and the different materials we may possibly use to create our mobile greenhouse.

### 2.2.2. Design Criteria

Our objective is to design a mobile greenhouse for Zane Middle School's seventh grade biology students. The design must be an efficient mechanism used to transfer Zane Middle School student's biology experiments from inside to outside, and back. The greenhouse will be stored inside at night and outside during the day. A typical experiment is an annual plant seedling in a Dixie cup. The design criteria can be broken up into four main components: size, mobility, safety, and maintenance.

2.2.2.1. Size

The design must easily fit through the classroom doorway. The maximum width must be less than thirty-six inches, minus the length that the door obstructs the doorway. The maximum height must be less than eighty-four inches, minus the height that the water guard that obstructs the doorway. The design must have an efficient use of space, it must be able to hold up to 150 experiments and easily fit in the classroom without obstructing student workspace.

2.2.2.2. Mobility/Usage

The design must be capable of easily transporting all experiments into and out of classroom; it must be mobile on the classroom floor, on concrete and over the water guard of the doorway. Since the best sunlight near the classroom is located on a patch of grass, it may be useful if the design is mobile on grass. Students must be able to access their experiments. The typical height of a seventh grade student and practical access ports should be considered. Seedlings require regular water, so a practical mechanism for easy watering should also be taken into consideration.

2.2.2.3. Safety

The design must be safe for students to operate. Sharp and potentially dangerous objects and materials should be avoided. The design should also reduce the risk of tipping or falling.

2.2.2.4. Maintenance

The design must require minimal routine maintenance and be durable enough to endure multiple seasons.

### 2.2.3. Plant Needs

#### 2.2.3.1. Water

Plants produce sugars for growth by performing photosynthesis; this process requires water, sunlight and carbon dioxide. Water and carbon dioxide are broken down to form glucose and oxygen. Water comprises a majority of the plant's physiology; it provides structure and support, regulates temperature, and transports nutrients to the plant. Water can replace the soil in hydroponic systems by increasing the amount of oxygen and nutrients in the water.

#### 2.2.3.2. Soil

Plants require nutrients from soil to maintain their health. The main nutrients are phosphorus, nitrogen, and potassium. Phosphorus aides in root growth, flower production, and helps maintain health and overall disease resistance. Nitrogen increases overall growth efficiency. Potassium also provides disease resistance and stimulates growth. Secondary nutrients, like magnesium, boron, chloride, iron, molybdenum and zinc, also aid in plant health. Each element benefits a specific plant function or structure. These nutrients will cause harm to the plant when given excess or insufficient amounts. Also, soil must have pockets of air that allow for the roots to have access to breath yet be compacted enough to support the plant structure. (Organic Grower School, 2008)

#### 2.2.3.3. pH

The pH of the soil affects the plant's ability to grow by determining its the ability to absorb nutrients in the soil. Ideal conditions are a neutral pH between 6.6 and 7.3. There are many ways to alter the pH of the soil to achieve desired levels. (Organic Grower School, 2008)

#### 2.2.3.4. Sunlight

Sunlight is a fundamental need for most plant life. Plants utilize solar energy in photosynthesis to break down water and carbon dioxide to form glucose. The amount of sunlight needed by a single plant varies from species to species depending on the amount of sunlight available in their native environments.

Sun light is comprised of multiple wave lengths and colors. The ones that aid plants the most of growth are sections of the spectrum that produce red and blue light. In most cases, the higher the amount of sunlight the more glucose the plant can produce.

If the change in light is dramatic the leaves may become damaged. If so, the leaves will grow a layer of wax for protection. Light duration is the amount of time a plant is exposed to sunlight in a given day. Photoperiods can also be defined this same way. Short day plants respond to shorter photoperiods whereas Long day plant flower in response to long photoperiods, and neutral plants flower regardless of photoperiods. (Mary Small 2016)

#### 2.2.4. Materials

##### 2.2.4.1. Requirements

A greenhouse maintains ideal growing condition by allowing light and UV rays of the sun to enter but not exit. The material of the walls are transparent and traps air in the structure so that the climate can be controlled with proper ventilation. As a result, the plants grow at their preferred climate. Therefore, the greenhouse must be transparent, durable, impermeable, and breathable.

##### 2.2.4.2. Potential Frame Materials

###### 2.2.4.2.1. PVC (polyvinyl chloride) Pipe

PVC pipes are typically used for water distribution. It is a durable substance that is flame resistant. At 122 degrees Fahrenheit, PVC pipe can withstand pressures up to 0.95 MPa. PVC pipe is susceptible to weathering and UV irritation. The severity of the degrading will depend on the amount of sunlight it is exposed to and how long the exposure lasts. Thus the material becomes weaker faster and is less effective in areas like Saudi Arabia, where there is constant sunlight on the pipe. Another factor in the decomposition of the pipe is how it is orientated. According to experiments done, the fracture toughness of a side exposed to sunlight is 40% lower than the side that was not facing the sun. Weathering can also cause the pipe to lose its original color. (Merah et. al, 2003)

#### 2.2.4.2.2. CPVC (chlorinated-PVC) Pipe

CPVC has similar properties to PVC pipe, except it is post-chlorinated PVC pipe designed to be an even stronger material (Merah 2007). The benefits of chlorinated-PVC are that the material is less corrosive, and able to withstand extreme temperatures (Merah et. al 2003). CPVC pipe is also able to withstand 0.45 MPa more than PVC, at 122 degrees Fahrenheit (Merah et. al 2003). CPVC pipe has been implemented in cities and in places with extreme weather conditions (like Saudi Arabia) rather than PVC because it is a more durable substance (Merah, 2007).

#### 2.2.4.2.3. Wood

Wood is also a durable substance if taken care of properly. However, wood can degrade due to biological threats, such as parasitic organisms or fungi, or because of elemental wear, like wind and rain. Wood is also flammable, but is unaffected by hot surrounding temperature; it has a high specific heat and will not combust due to natural temperatures. Wood may expand, at the scientific level, when the surrounding humidity is less than 0%. (Özen, 2016).

#### 2.2.4.2.4. Windows

The greenhouse glazing material taken into consideration for our mobile greenhouse include: glass, fiberglass, plastic polyethylene, plastic polyvinyl Chloride (PVC or Vinyl), plastic polycarbonate, and acrylic Plexiglas. The advantages and disadvantages of the multiple materials such as the durability, maintenance, insulation, and muchare discussed in Table 2-3.

#### 2.2.4.2.5. Limiting Factor

The paneling material will ultimately affect the framing of our greenhouse; e.g., glass, which is heavy, requires a sturdy frame versus plastic polycarbonate, lighter weight that could be held by a PVC frame (Blom, 1985). Glass would make a durable and good insulating material, but it would be a safety hazard as well as be expensive to install and replace (Worley, 2009). The advantages and disadvantages of the multiple materials such as durability, maintenance, and insulation for the wall of the greenhouse are listed in Table 2-3.

Table 2-3 Advantages and Disadvantages of Materials

| Material Type | Advantages | Disadvantages |
|---|---|---|
| Glass | • Durable (25+ years)<br>• Translucent<br>• Low maintenance Good Insulation<br>• Maintains humidity | • Safety hazard<br>• Expensive to install and replace<br>• Needs a sturdy, well-structured<br>• greenhouse frame |
| Fiberglass | • Durable (15+ years)<br>• Translucent when first purchased<br>• Easy to install | • Expensive<br>• Color changes over time, becomes less translucent<br>• Permeable, some fiberglass material does not allow UV to penetrate through |
| Plastic. Polyethylene | • Low cost<br>• Easy to install<br>• Translucent | • Not durable, broken down by UV rays (8+ months)<br>• Permeable material that loses heat at night (Allows heat that is reflected from inside plants to escape through material) |
| Plastic Polyvinyl Chloride (PVC or Vinyl) | • Low cost (Costs more than Polyethylene)<br>• Easy to install Attracts dirt, needs to be maintained<br>• Translucent enough | • Durable but is broken down by UV rays overtime |
| Plastic polycarbonate | • stronger than polyethylene<br>• easy to cut | • Expensive<br>• Degrades over time (10+ years)<br>• Color changes over time, becomes less translucent |
| Acrylic Plexiglas | • Translucent<br>• Will not discolor with age | • Expensive<br>• Safety hazard (flammable) |

2.2.4.3. Types of Greenhouse Structure

2.2.4.3.1. Attached lean-to

A lean-to greenhouse is a structure that utilizes a wall or side from an already established building to make up one side of greenhouse. The length and height are limited by the existing wall. An advantage to a lean-to structure is that it can use resources such as electricity and water from the attached building. The disadvantages of a lean-to are that size is limited, the building is going to block the sun half the time, while temperature and ventilation are hard to completely control. (Freeman 1997).

2.2.4.3.2. Attached even-span

An attached even-span greenhouse is a combination of a lean-to and a freestanding greenhouse. It is attached to an existing wall of a home or building, except that it is attached at the end where the roof forms a triangle like shape. Everything else about the structure is free standing. The benefit of an attached even-span is that it is larger and can hold more plants than the lean-to. Disadvantages of an even-span are that the structure can be more expensive to build and maintain. (Freeman1997).

2.2.4.3.3. Attached window-mounted

A window-mounted greenhouse is a flat glass window that is replaced with an all glass structure with a dimension that has shelving and room for plants to grow. The size of the greenhouse depends on the size of the window replaced. Generally, installing this greenhouse requires minimal tools because the greenhouse is prefabricated. (Freeman 1997).

2.2.4.3.4. Free Standing

Free standing greenhouses vary in size, shape, and location. They depend on the creativity of the designer. However, they are independent structures with sidewalls and a roof. They may require heating or ventilation systems depending on the surface area and climate. However, the gain more heat during the day. Popular freestanding greenhouse structures include the dome, gothic arch, tri-penta, gable roof, and a-frame. (Freeman 1997).

2.2.4.3.5. Mobile

A mobile greenhouse can be large, however, size will be limited by the force available to make it mobile. Examples of mobile greenhouses that have been built and patented are below.

2.2.4.3.6. Portable Greenhouse Cart

This portable greenhouse was invented by Mary K. Shepard, and patented in 2000. She implemented free-standing greenhouse structures and features in her design. However, she shrank the structure and used a watertight tub or pan to provide a fluid containing reservoir for the soil with the ability to drain via a small passage connected to the watering system in the tray. The watering system has spaced nozzles placed within the framework powered by water pressure coming out of a hose or similar high pressure water source. Attached on top of the side of the tub is a U-shaped framework to hold a clear and translucent awning like cover. Attached to the bottom half of the tub are the wheels, large and similar to bicycle wheels, that make it mobile. Inside the canopy are racks that house the plants. (Shepard 2000).

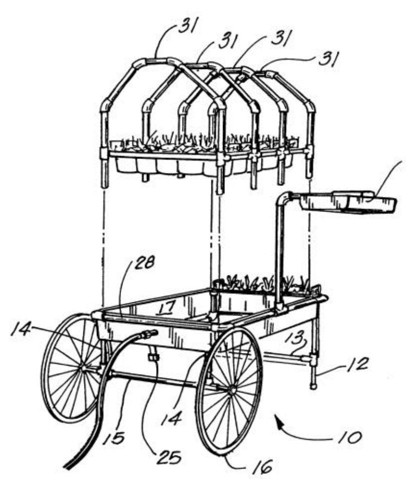


Figure 2-2-1 Portable Greenhouse Cart

http://www.google.com/patents/US6622425

2.2.4.3.7. Wheel-About Greenhouse

The Wheel-About Greenhouse was published in 1989 by Kevin J. Smith. It is a simple design where a transparent cover with a fixed shape is placed onto a lower bed with the same proportions as the top. The base portion and the top cover are double walled to provide insulation for the plants. The wheels are attached to the bottom and a handle is attached to make mobilization easier for the operator of the greenhouse. On the inside of the cover are equally spaced sprinklers to water the plants.

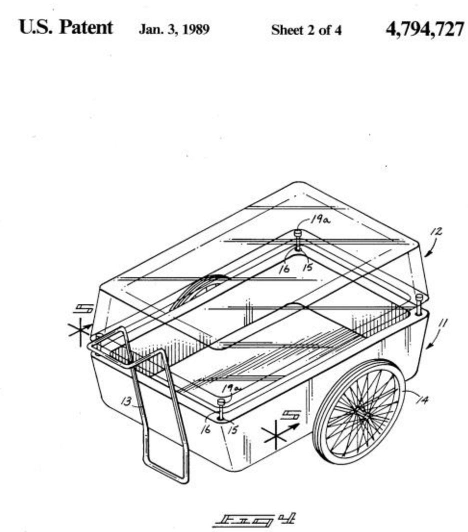


Figure 2-2-2 Wheel about Greenhouse Patent

https://www.google.com/patents/US4794727

2.2.4.3.8. Portable Electric Greenhouse

This greenhouse was designed by Gerard H. Risacher and patented in 1963. His design is a base (including side walls) made up of insulating material that makes a box like area and a clear removable cover (to provide ventilation). For best insulation, Risacher found that the walls should be around three-fourths of an inch thick. The insulating material suggested in the description is something as simple as Styrofoam. In the box area will be a tray, filled with soil, that will hold all of the plants. The electrical part comes from the heating element at the bottom of the base just below where the tray is supposed to be placed. The inventor considers his invention to be portable because it is small enough to be carried and transported for use in homes, offices, etc.

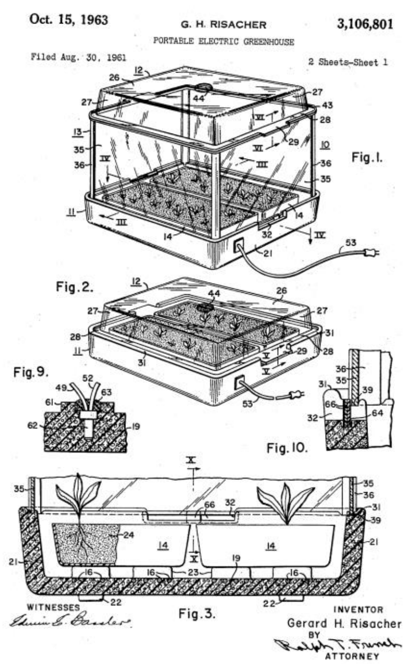


Figure 2-2-3 Portable Electric Greenhouse

https://patentimages.storage.googleapis.com/pages/US3106801-0.png

2.2.4.4. Wheels

We will include research on wheels that can easily maneuver through a classroom and that can easily roll onto and off grass.

# 3. Alternative Solutions

## 3.1. Introduction

Section 3 will cover the benefits and detriments of alternative greenhouse designs. Brainstorming sessions occurred in order to develop potential designs for a mobile greenhouse. Every alternative described in this section satisfies the project criteria. A total of six potential solutions, developed during the brainstorming sessions, are presented in this section.

## 3.2. Brainstorming

A total of two brainstorming sessions were held. One was unstructured, using a whiteboard, to allow for a free flow of ideas. The second session was structured using a formatted document. The purpose of brainstorming was to share each other's greenhouse design ideas. We then combined and built upon those ideas to develop our well thought out alternative solutions.

## 3.3. Alternative Solutions

The following alternative solutions were developed during the brainstorming sessions. A visual aid was drawn and a detailed description was written for the top six alternatives.

### 3.3.1. Rotating Soda Can Model

The rotating soda can model, shown in Figure 3.3.1, is a cylinder shaped greenhouse. The circular shaped base would have wheels attached to the bottom and have shelving within the cylinder. The student’s experiment’s rests on a vertical shelf within the cylindrical unit. The cylindrical shape will be enclosed with a transparent material that would protect the plants as well as provide the ideal climate for growth. The greenhouse would be designed to rotate to allow more sunlight to enter and provide access for the students. This design would require a special set of materials to keep the cylindrical shape.

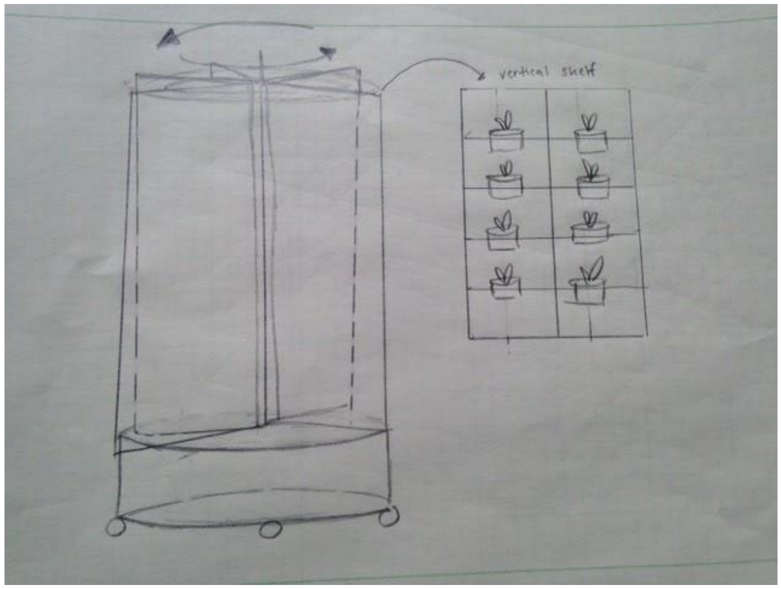


Figure 3-1 Soda Can Model draw by Carlos Cruz III

3.3.2. Snow Globe Model

The Snow Globe Model, shown in Figure 3.3.2 is a greenhouse design that is composed of a half sphere attached to a cylindrical base. The snow globe model may require multiple shelving structures in order to accommodate the total amount of experiments. The upper portion of the design is constructed using a translucent material that will produce a half-sphere-like structure. The bottom will be constructed using a durable material, like wood, and have wheels attached to make it mobile.

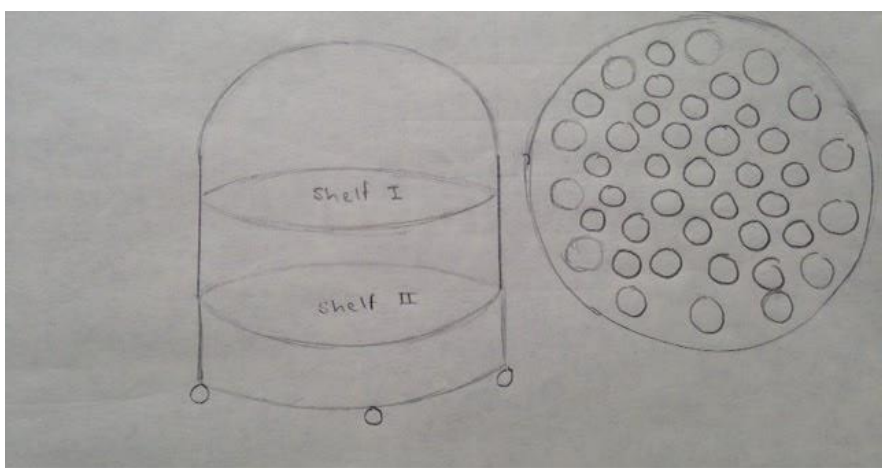


Figure 3-2 Snow Globe Model drawn by Carlos Cruz III

### 3.3.3. The Wire Curtain

The Wire Curtain method, shown in Figure 3.3.3, uses tension wires along anchor points to form an enclosed shape. The wires used can be made of metal or heavy duty string. The anchor points of the wire are made of a rigid material and attached by screws to the base. Experiments will sit together on a common level. The base will be elevated off the ground and have wheels attached to the bottom. A transparent material is hung over the structure and slides open along the wire for accessibility.

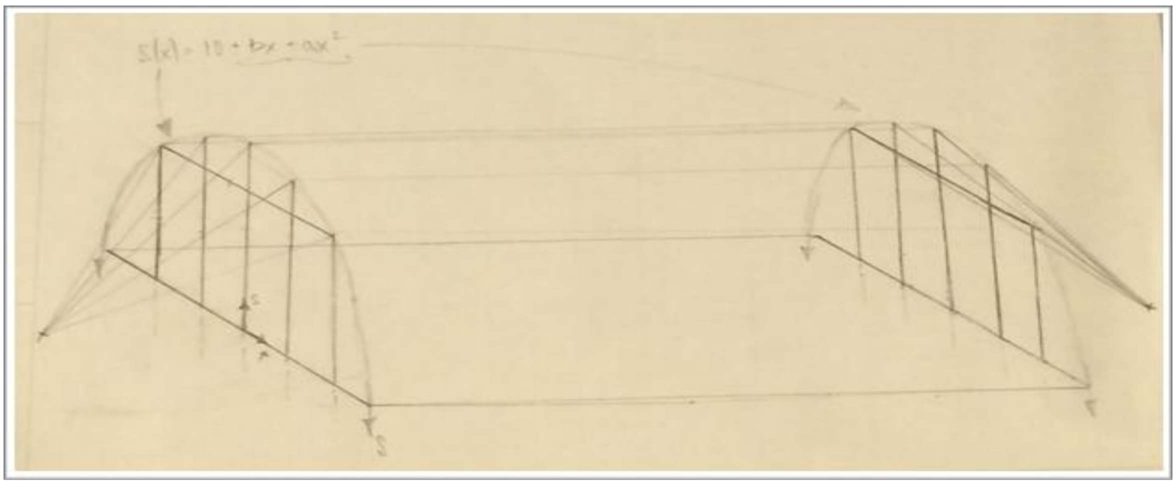

Figure 3-3 Wire Curtain Model drawn by John Jensen

### 3.3.4. The Stacked Totes Cart

The Stacked Totes design, shown in Figure 3.3.4 uses clear totes to organize and enclose experiments. The number of totes used is determined by the number of experiments that are needed to be accommodated. The totes are stacked vertically to minimize the occupied space when stored. A flat bottomed cart with tote holders is used to transport experiments.

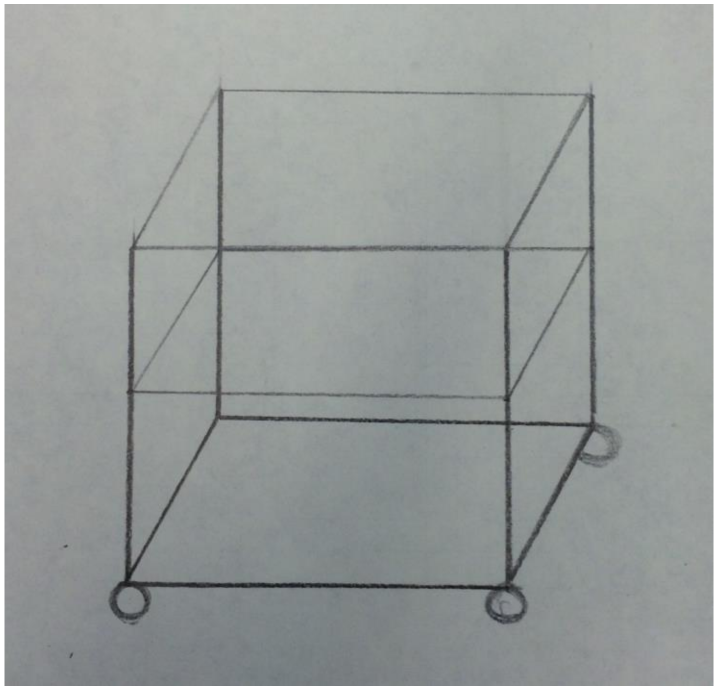

Figure 3-4 The Stacked Totes Model drawn by John Jensen

### 3.3.5. The Barn

The Barn design, shown in Figure 3.3.5, consists of a rectangular frame constructed of treated wood. The framed walls have corrugated plastic inserts for safety, lightweight, and cost-effective reasons. The Barn has a rectangular base, a triangular roof, and wheels attached at the bottom. There will be cargo space for storing materials. The roof can be manually propped open to provide access to the 7th grade students germination projects. Both side walls act as a door and can be opened for increased accessibility. Inside the Barn, two wooden trays with dimensions of 26.25" x 41.25" are placed to hold 75 solo cups each. The wooden trays can be pulled out for quick access to the germination projects.

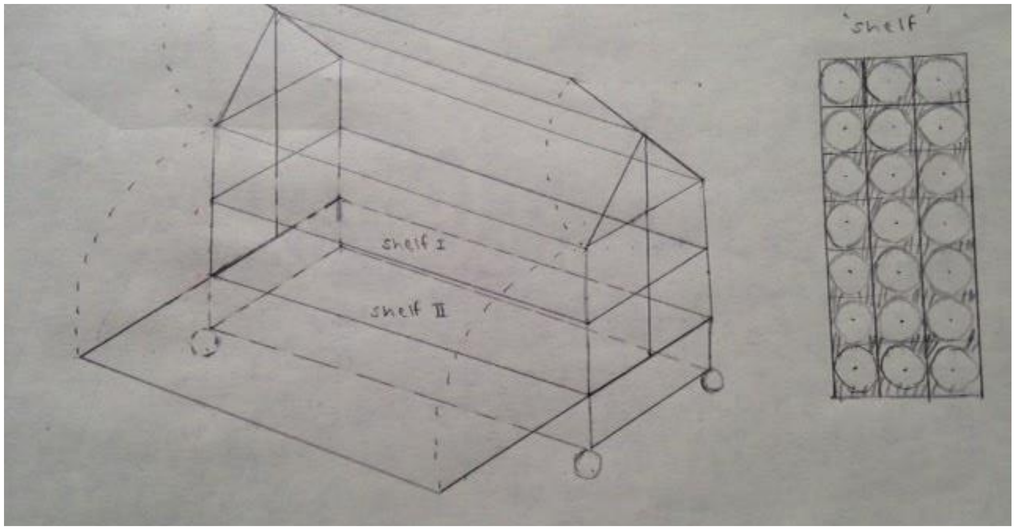


Figure 3-5 The Barn House Model drawn Carlos Cruz III

### 3.3.6. The Starter Box

The Starter Box, shown in Figure 3.3.6, consists of a rectangular frame made of treated wood, walls made of corrugated plastic and a shower curtain enclosure. The shower curtain can be pulled aside to access the germination projects. The Starting Box has a rectangular base and roof with wheels attached at the bottom. Inside the Starting Box, there are two wooden trays with dimensions of 26.25" x 41.25" to hold 75 solo cups each. The wooden trays can be pulled out for accessibility to the students' projects.

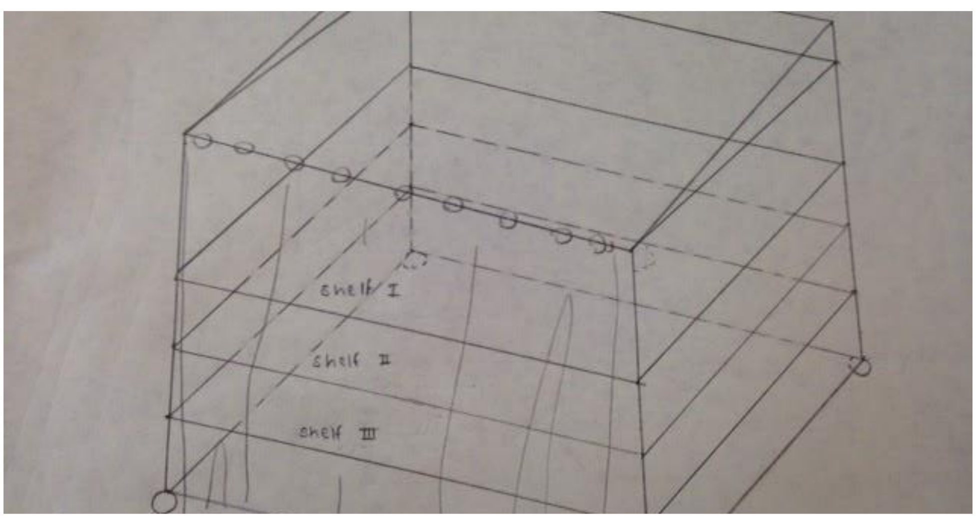


Figure 3-6 The Starter Box

# 4. Decision Process

## 4.1. Introduction

The focus of Section 4 is the final design as well as the method utilized to derive the final design solution. Employing the Delphi Method, this section evaluates the following alternative design solutions from Section 3 to make an informed and concise decision. Each alternative design is evaluated on the selected criteria from Section 2 to decide which would be the best fit for the client.

## 4.2. Criteria Definition

The following are the definitions and selected criteria from Section 2:

- Safety- The greenhouse should pose minimal danger to students and adults handling it. The design should also remain safe when handled inappropriately, as well as discourage any forms of mishandling.
- Durability- The greenhouse should be able to last multiple school years and withstand seasonal weather. It should be able to be sustained with minimal maintenance.
- Portability- The greenhouse should be able to be moved with minimal effort and with minimal risk of damaging the greenhouse itself or posing any danger to those moving it.
- Cost- The greenhouse should be both a low cost to build and maintain throughout its use.

## 4.3. Solutions

The following list of alternative solutions were analyzed and have detailed descriptions in Section 3.

- Rotating Soda Can
- Snow Globe
- The Starter Box
- The Barn
- Wire Curtain
- Stacked Totes

## 4.4. Decision Process

The decision making technique, known as the Delphi Method, is used to determine the best alternative solution. The first step is to assign a weight to the criteria. The weight scale is based on a highest possible value of 10, as seen in Table 4.1. The assigned weighted values for the criteria are determined by a group consensus. The second step taken by our group is to assign a value of 0-30 for each of the alternative solutions, as seen in Table 4.2. A 30 is assigned to the alternative solution that meets the criteria perfectly. The group came to an agreement as to what these rankings would be as well. The last step is to multiply the alternative solution rankings (0-30) by the criteria weighted values (0-10). The sum of the scores come to a total to determine the final solution.

Table 4-1 Weighted Criteria

| Criteria | |
|---|---|
| List | Weight |
| Safety | 10 |
| Portability | 9 |
| Durability | 6 |
| Cost | 6 |

Table 4-2 The Delphi Method

| Criteria | | Solutions | | | | | |
|---|---|---|---|---|---|---|---|
| List | Weight | Rotating Soda Can | Snow Globe | The Starter Box | The Barn | Wire Curtain | Stacked Totes |
| Safety | 10 | 20 / 200 | 24 / 240 | 24 / 240 | 24 / 240 | 12 / 120 | 18 / 180 |
| Durability | 6 | 16 / 96 | 20 / 120 | 27 / 162 | 24 / 144 | 22 / 132 | 24 / 144 |
| Portability | 9 | 22 / 198 | 15 / 135 | 24 / 216 | 25 / 225 | 16 / 144 | 25 / 225 |
| Cost | 6 | 10 / 60 | 21 / 126 | 20 / 120 | 20 / 120 | 26 / 156 | 28 / 168 |
| Totals | | 554 | 621 | 738 | 729 | 552 | 717 |

## 4.5. Final Decision

The results of the Delphi Method indicate that The Starter Box is the best solution to use as a mobile greenhouse for Zane Middle School. The Starter Box has the top safety and durability ranking, which gave it the highest ranking. Since The Barn scored extremely close to The Starter Box, we will try and merge the better qualities of The Barn with The Starter Box.

## 5. Specification of Solution

### 5.1. Introduction

Section 5 includes a detailed description of the final solution selected. An AutoCAD drawing showing multiple views of the solution is included to depict the design in greater detail. Within this section are tables of costs which analyze team design hours, material costs, and maintenance costs. Also included are step by step instructions on how to implement and use our design. Finally, closing the section is the results of our design.

### 5.2. Solution Description

The Box, shown in Figure 5.1, is a simple design for a mobile greenhouse. The Box is designed to house 150 plant experiments. Each experiment will be take up an estimated 66.8 cubic inches plus the height that the plant will grow (the team decided to give the plant an estimated foot to grow). Keeping in mind the greenhouse should be functional within a classroom, the team decided to make The Box 24" x 56" x 48". These dimensions make the greenhouse small enough to fit in the client's classroom but big enough to house all of the student's experiments. The Starting Box is made up of a wooden framework for ultimate stability and durability. The framework will be attached to four wheels on each corner of the box to create mobility. The corrugated plastic roof and reinforced woven polyurethane greenhouse plastic allow sunlight to seep through and reach plant experiments, while trapping heat within the structure to create a preferable climate. Within the greenhouse are racks that will hold two layers of experiments. Each rack will hold approximately 75 experiments. The racks will be made out of wood and will be a flat smooth surface make the greenhouse adaptable for a variety of experiment sizes and materials. Also included in the design is easy accessibility for students to handle their projects through racks that are able to slide out of the framework.

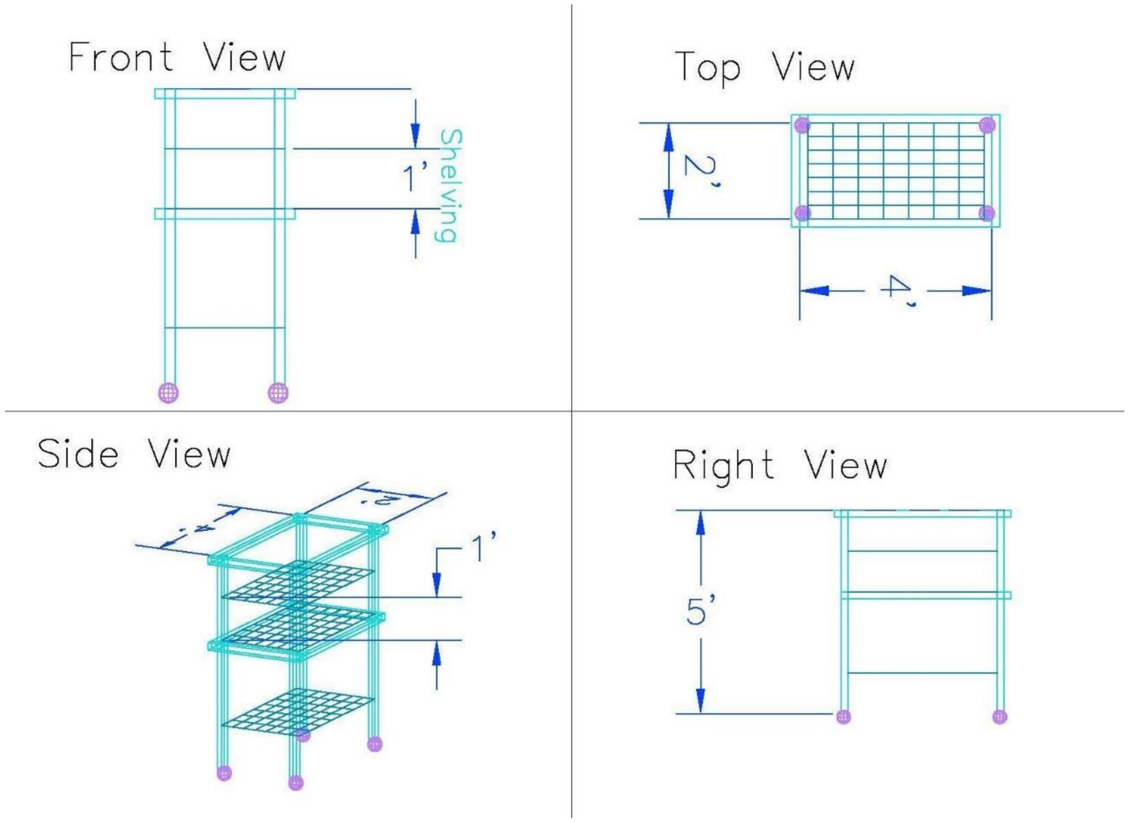


Figure 5-1 The Starter Box CAD drawing by Julie Hernandez

5.2.1. The Frame

The framework is in a simplistic box shape. Treated wood was used for the the framework to make the product more durable, and therefore have little to no future maintenance for the client. Because the greenhouse will be used by middle school students the team decided to make the frame sturdier using four 4x4 thick posts at each corner to add more weight and support. The side pieces of wood are also bigger than they needed to be for excess strength. Then we added 2x2 pieces of wood vertically to the center of the length to add sliding racks. Before the framework was constructed, the wood was cut into the desired dimensions, washed, and sanded down. Then the wood was painted "Aquamarine" to make the design more fun and engaging for the students.

5.2.2. The Walls

Corrugated plastic is used as the material for walls because it is durable material as well as donated. Before the plastic was attached to the greenhouse, it was cut into the desired length and cleaned. The plastic is used as all four walls of the greenhouse. The material allows sunlight to reach the plants and while insulating the greenhouse to provide a desirable growing temperature. It will also act as a protective barrier for the plants from the outside disturbances.

5.2.3. The Roof

The roof is also made out of corrugated plastic. It was also designed to be a rainwater catchment system. It was placed on the framework tilted towards one corner. The slope of the roof did not have to be extreme in order to cause rainwater to naturally flow towards the one corner, where a container will be able to catch all of the water.

5.2.4. The Wheels

The wheels were attached to each of the four posts at the corners of the box framework. The wheels are durable enough to withstand the weight of the greenhouse and handle the geographies of the areas where it will be placed. They are also clear and look interesting to make the greenhouse more enjoyable to the young students.

## 5.3. Cost Analysis

### 5.3.1. Design Costs

The design costs show the number of hours the Four Tall Redwoods spent of the design project. Figure 5.2 shows the distribution of hours for the individual phases of design.

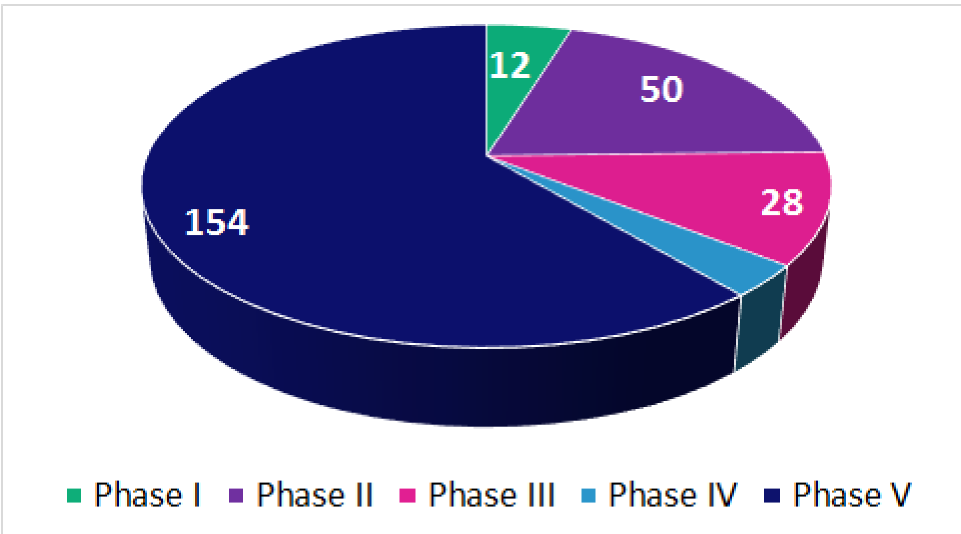


Figure 5-2 Team Design Hours

### 5.3.2. Material Costs

Table 5.1 indicates the cost of materials used in the making of The Starter Box. The total amount spent was $188.00. Because the team received a lot of donations, the cost column indicated the cost of the project including the projected cost of the donated items, while the total column shows the total amount the group paid.

Table 5-1 Material Costs

| Quantity | Material | Source | Cost ($) | Total ($) |
|---|---|---|---|---|
| 2 | Paint | ACE Hardware | 20 | 40 |
| 1 | Lumber | Thomas Home Center | 5 | 5 |
| 1 | Lumber | Thomas Home Center | 23 | 23 |
| 2 | Reclaimed Lumber | Location | 75 | Donated |
| 1 | Plastic Paneling | Location | 30 | Donated |
| 1 | Woven Polyurethane Plastic | Location | 100 | Donated |
| 2 | Paint Brushes | ACE Hardware | 17 | 34 |
| 4 | Wheels | ACE Hardware | 6 | 24 |
| 1 | Duct Tape | ACE Hardware | 10 | 10 |
| 2 | Handles | ACE Hardware | 7 | 14 |
| 2 | Pack of Magnets | ACE Hardware | 7 | 14 |
| 1 | Pack of Metal Washers | ACE Hardware | 1 | 1 |
| 1 | Pack of Screws | Thomas Home Center | 6 | 6 |
| 1 | Pack of Screws | Thomas Home Center | 7 | 7 |
| 1 | Pack of Screws | ACE Hardware | 10 | 10 |
| **Total Cost** | | | **$468.00** | **$188.00** |

### 5.3.3. Maintenance Cost

The Box has relatively low maintenance due to its durability and simplicity. However, table 5.2 shows projected maintenance costs.

Table 5-2 Maintenance Costs

| Required Maintenance | Frequency | Projected Cost |
|---|---|---|
| Clean Windows | 1 year | $ 2.99/ 5 years |

## 5.4. Instructions for Implementation and Use of Model

The Box mobile greenhouse will be housed in Betsy Elkington's classroom and wheeled into the sun when in operation. The experiments themselves can be placed on shelving within the greenhouse. The shelving is spacious allowing for the students experiments to grow up to a foot high without being disturbed by the roof or shelf above it. The design provides has plenty of room for each individual experiment. Once the experiments are settled, the greenhouse is ready to be placed outside for as long as the instructor desires.

## 5.5. Results

The result of building the final design will be a functioning mobile greenhouse. The structure is sturdy and able to withstand use for many years to come. Each year the greenhouse will be able to house all of the experiments for all of Betsy Elkington's biology students. Students will be able to watch their plant grow healthy and learn about the germination process.

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# 6. Appendices

## 6.1. Group Project Hours

Our group spent a total of 12 hours on Phase I, 50 hours on Phase II, 28 hours on Phase III, 8 hours on Phase IV, and 154 hours on Phase V. A total of 252 was spent for all the Phases. Figure 6-1 displays our design hours per each phase.

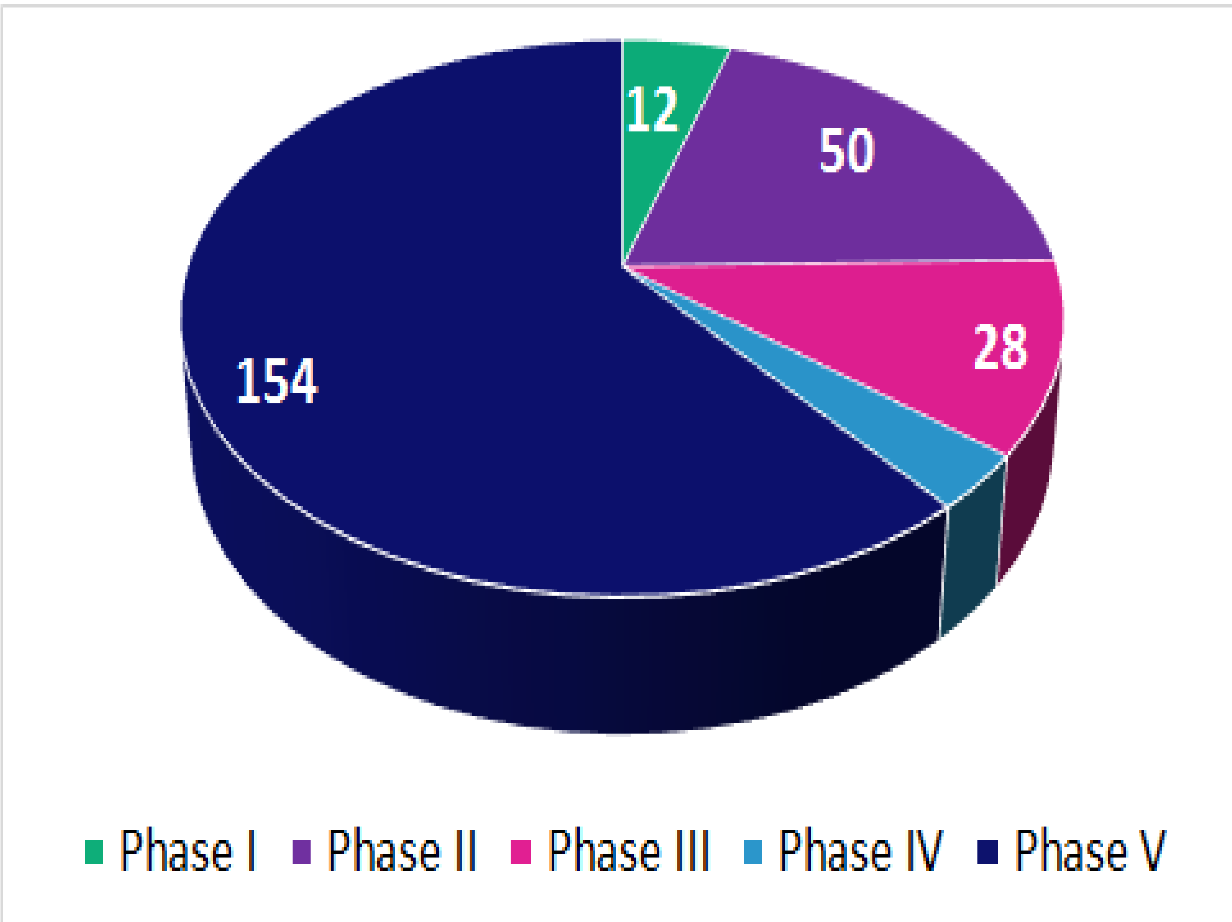


Figure 6-1 Design Hours

## 6.2. Appendix A: Brainstorming Session

We had two brainstorming sessions to explore [otiential alternative solutions. Figure 6-2 shows notes from our first brainstorming session. Figure 6-3 shows notes from our second brainstorming session.

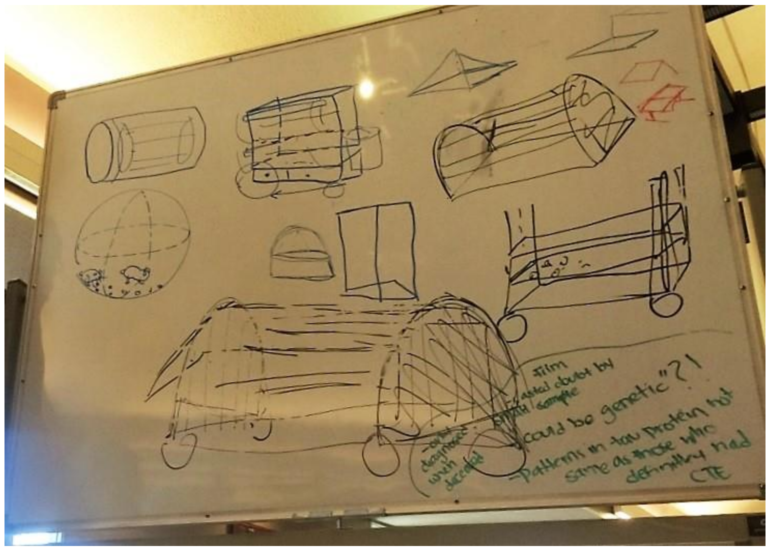

Figure 6-2 First Brainstorming Session

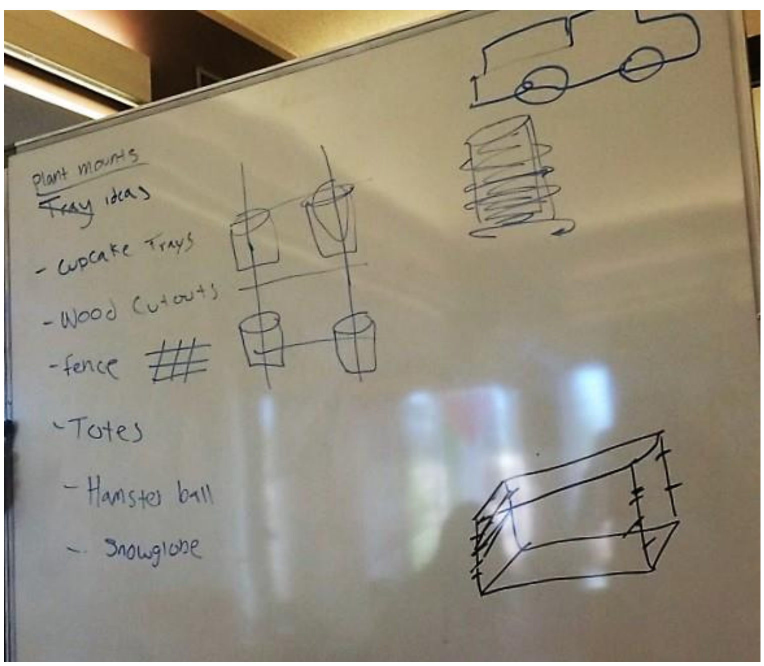


Figure 6-3 Second Brainstorming Session