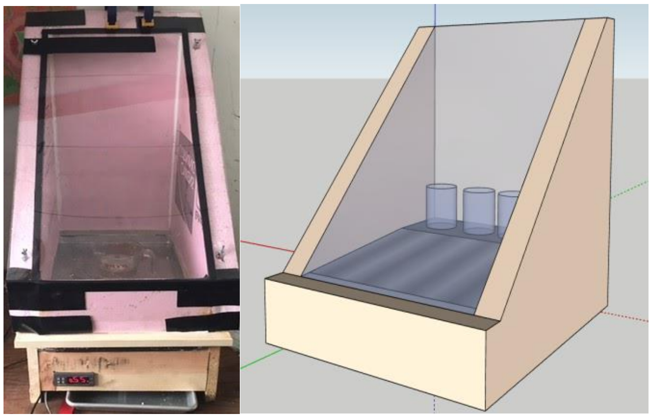

Lean With It Rock With it

TEAM ZANE-IACS

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HUMBOLDT STATE UNIVERSITY | ENGINEERING 215 SPRING 2020

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1 Problem Formulation

1.1 Introduction

This section defines background information on the problem at hand, discusses the objective statement, and displays a black box model.

1.2 Background

This project is done by Team Zane-iacs in Spring 2020 at Humboldt State University in the class ENGR215. The client for this project is the teacher Ms. Stewart at Zane Middle School. Zane Middle School is a STEAM school which means they have an emphasis in science, technology, engineering, arts, and math. Ms. Stewart wishes to teach her kids about chemistry through the use of a desalination device. Ms. Stewart desires an electrically powered desalination device that is effective in demonstrating the separation of salt and water. This device must also be small enough to be stored in a classroom environment.

1.3 Objective Statement

To construct a reliable, electrically powered, and compact desalination device intended for the use of educating children on the subject of chemistry.

1.4 Black Box Model

Figure 1-1:Black box model demonstrating goal of the project.

2 Problem Analysis and Literature Review

2.1 Introduction to Problem Analysis

The problem analysis section defines the specifications and criteria used to define the problem put forth in the objective statement. This section includes specifications, considerations, criteria and constraints, usage, and production volume.

2.1.1 Specifications and Considerations

Specifications and considerations are created through project research and interviews with the client. They set forth target goals to meet or keep in mind throughout the design process.

2.1.1.1 *Specifications*

Specifications describe project parameters necessary to meet the overall goals of the project. This desalination device must allow viewing of evaporation, condensation, and eventual salt crystallization. This device must be durable enough to last for 20 complete cycles of evaporation over a 5-year time period. This device must be small enough to fit on the counter-top in the classroom. The device should also be light/small enough to be moved by one adult or two 12-year-olds.

2.1.1.2 *Considerations*

This device will use safe methods for producing heat for evaporation including UL listed heating elements. The teacher is the one that will be placing solutions created by the middle school students into the desalination device. The teacher will have the most interaction with the device.

2.1.2 Criteria and Constraints

The criteria are the standards that the project is going to be judged upon. The constraints define the parameters that need to be met to satisfy the client. The project must satisfy all criteria through established constraints.

Criteria:	Constraints:
Efficacy	Better than the current desalination device used in the classroom
Aesthetics	More appealing than taxidermized ducks in the classroom.
Cost	<= $400
Power Consumption	More efficient is better
Educational Value	Be able to be seen by 6 children from at least 6 feet away
Safety	Safer or as safe as the operation of electronic devices such as a computer or television

2.1.3 Usage and Production Volume

Usage refers to how often the device is going to be used. It also represents the target demographic of the device. Production volume is the total amount of devices that will be created.

2.1.3.1 *Usage*

This desalination device will be implemented at Zane Middle School. The classroom that it will be in is Ms. Stewart's science classroom. The desalination device is going to be used four times during a two-week period of the school year. Around 20-30 students will usually be in the classroom during desalination.

2.1.3.2 *Production Volume*

One desalination device will be produced.

2.2 Introduction to Literature Review

The purpose of this literature review is to culminate appropriate research in order to generate appropriate solutions and create a working desalination device at Zane Middle School. Many different sources are utilized in order to maximize the amount knowledge that is needed to solve the problem formulated in Section 1.

2.2.1 Client Interview

The primary client contact for Zane Middle School is the science teacher Julie Stewart. Ms. Stewart is requesting a desalination device for her classroom. This device will serve as an educational aid to meet several goals for the 7th grade science requirements.

2.2.2 History of Desalination devices at Zane Middle School

The current method of teaching desalination uses plastic bottles connected by straws, and proves to be ineffective, Figure 2-1.

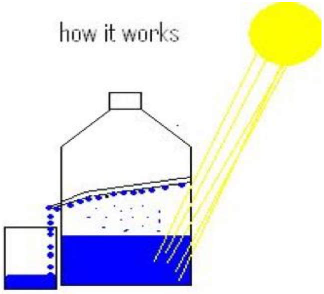


Figure 2-1:Plastic bottle desalination device example diagram: https://www.instructables.com/id/plastic-bottle-desalination/

These desalinations proved to be ineffective at evaporating water due to poor solar gain available in Eureka (Stewart 2020).

2.2.3 Design Specifications

The classroom needs a desalination device that adheres to the following design criteria.

2.2.3.1 *Operational Goal Criteria*

The device should be able to completely evaporate saltwater, and have the end products of salt crystals and purified water. The device should desalinate water in a time frame that is optimized for the teaching environment, less than one week but longer than 24 hours. The device should make it easy for students to view the desalination process and its products. The preferred method of generating heat for desalination shall be provided by plugging into the available 120 A/C outlets.

2.2.3.2 *Safety and Storage Criteria*

The device should be as safe as possible, using non-breakable materials if available. The device should be easy to move and store for 12-year-old students. To facilitate storage and usage, this device should be smaller than .75 cubic meters.

2.2.4 Standards for Drinking Water Salinity

2.2.4.1 *Contaminant Categorization*

Unlike other contaminants, salinity in drinking water does not represent an immediate risk to human health and therefore does not have an MCL (maximum contaminant level) associated with it. Salt is considered to be a secondary contaminant with non-mandatory regulations for salt concentrations in drinking water. Salt levels are reported as SMCL's (secondary maximum contaminant levels) (EPA 2020).

2.2.4.2 *California Standards for Salinity*

California has two measured water quality parameters related to salinity, EC (electrical conductivity) and TDS (total dissolved solids). EC levels can be from 900-1600 micro Siemens/centimeter (a conductivity unit). TDS levels should be 500-1000 micrograms per liter (Groundwater Information Sheet 2017).

2.2.4.3 *Industrial Desalination Salinity Results*

Industrial desalination technologies produce water that falls well below the SMCL thresholds for EC and TDS. Reverse Osmosis treats sea water to 70-350 micrograms per liter. TDS (Lenntech, Post Treatment 1998). Distillation produces water with <25 parts per million TDS (Sherer 2010).

2.2.5 Impacts of Desalination

2.2.5.1 *Economic Impacts*

Desalination is one of the most expensive ways to produce drinking water. Desalinated water costs $3-4 per gallon and 14 kilowatt-hours per 1000 gallons to produce. (Schirber 2007).

2.2.5.2 *Environmental Impacts*

Desalination plants impact maritime environments. Marine creatures are sucked into the plant intakes and die in processing. Discharging highly concentrated salt water, also known as brine, can create localized toxic environments further damaging marine creatures and reefs. In 2015, the California State Water Resources Board amended the Water Quality Control Plan for the Ocean Waters of California to prevent environmental damage from desalination (Waterboard 2019).

2.2.5.3 *Health Impacts*

Reverse Osmosis desalination removes salt but leaves other contaminants such as spilled petroleum products, industrial toxic waste, and toxic algae byproducts (Food Water Watch 2009). This water also has elevated levels of boron and other minerals that can create health problems if they are over consumed. As such, secondary treatment of RO desalinated water is required to make it safe for human consumption (Lenntech, Boron 1998).

2.2.6 Desalination in Schools

This section provides examples of desalination devices across schools in the United States to gather preliminary design information.

2.2.6.1 *Zane Middle School Projects*

Zane Middle school currently assigns an individual project to its seventh-grade students as a way to teach desalination. In this project students build a desalination device out of two water bottles connected with a straw. This project is intended to achieve a chamber (water bottle) of clean distilled water and another chamber (water bottle) of salt. This project has not been successful in desalinating the water. In an effort to make this project successful, heat lamps have been implemented to speed up the condensation and collection. Despite this added thermal energy, the project was still unsuccessful.

2.2.6.2 *High School Projects*

Farmington High School in Farmington, MN desalinated ocean water by distillation in an earth science lab in 2013. The students used a Bunsen burner, Erlenmeyer flask, a stopper with tubing, boiling chips, and a conductivity probe to complete this process. Saltwater was boiled and collected into a collection test tube submerged in ice water. The test tube collected the newly distilled water, and the Erlenmeyer flask contained the residual salt. (Buss 2013)

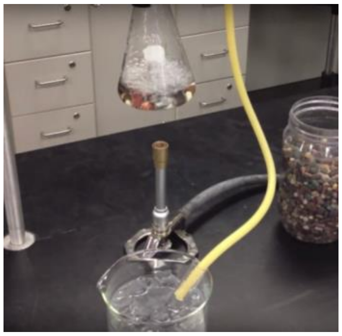


Figure 2-2: Desalination through distillation process. (Buss 2009)

2.2.6.3 *Desalination through Thermal Process*

Other projects include the use of two plastic containers and tin, using the thermal process approach. Students then “use a saltwater circuit to test the efficiency of their model desalination plant”. (Samson 2009)

Figure 2-3: An experimental thermal process desalination device. (Carleigh Samson 2009)

2.2.7 Pedagogy

This section outlines the Science Standard's which Zane middle school must follow. These standards include, the California standards, physical science, engineering standards, and the kinetic learning approach.

2.2.7.1 *Science Standards for 7th Graders*

In September 2013, California adopted the Next Generation Science Standards into the curriculum of public K-12 institutions. For grades 6-8, the Science Expert Panel approved the implementation of the Integrated Progression Model as the preferred model. This IPM conceptualizes topics taught in elementary school, which are then gradually developed in 6-8th grades through further implementation and understanding. (CDE 2013) Performance expectations for each grade were added in November 2013 to "support a logical flow of content and increasing complexity of concepts across grade levels". (CDE 2015)

2.2.7.2 *Next Generation Science Standards*

Zane Middle School abides by the guidelines set in place by Next Generation Science Standards. In grade 7, students are to develop models that describe particles, temperature, and states of pure substance when thermal energy is added or removed. (National Research Council 2012). Once students have finished middle school, they should be able to explain certain processes that are occurring at the molecular level. Students also should be able to apply this knowledge in the design and process of engineering chemical reaction systems.

2.2.7.2.1 Physical Science

Seventh-grade students learn about the Structure and Properties of matter, students then understand atoms and their composition and their physical and chemical quantities. Seventh-graders also learn about Chemical reactions, where they understand that substances react in characteristic ways, and in those reactions, the products have different properties than the reactants. Seventh-graders also learn the law of conservation of mass, where mass is neither created nor destroyed. Seventh-grader students also learn about the difference between endothermic and exothermic reactions. (DCI 2013)

2.2.7.2.2 Engineering Design

Seventh-grade students are also introduced to engineering design where they learn that solutions must be tested then modified based on the test result. In order to improve on the design, characteristics of the tested design may be incorporated into the new design. Seventh-grade students also learn “the more precisely a design task’s criteria and constraints can be defined, the more likely it is that the designed solution will be successful.” (DCI 2013)

2.2.7.3 *Kinetic Learning style*

At a young age, children are “open, perceptive, and experimental”. (Holt 1973) Children are open to new ideas, and pursue creative hands-on activities. Children are not afraid of making mistakes, and can patiently learn how reality works. However, when children are of age, “school is not a place that gives much time, or opportunity, or reward, for this kind of thinking and learning”. School, with its standardized testing and strict curriculum, can put stress on a child. “It is difficult for children to learn something when they are rushed, threatened, or given failing grades” (Hunt n.d) The pressure to earn a “good grade” can obstruct the creative learning style as a young child and “when we make children afraid, we stop learning dead in its tracks." (Holt 1973). These analyses suggest that a hands-on approach to learning and designing may be beneficial to the students’ learning ability.

2.2.8 Chemistry Basics

This section will explain basic terminology and concepts that are required to understand the chemistry of desalination. Desalination is the process of removing salt from water.

2.2.8.1 *Matter*

Matter is defined as anything that can occupy pace and has mass. Matter exists in three states: solid, liquid, and gas. As a solid, the volume and shape are definite. As a liquid, the volume is definite, while the shape conforms to its container. As a gas, matter will not have a definite volume or shape. A gas will conform to the shape and volume of the container it occupies. (Zumdahl and Zumdahl 2014)

2.2.8.2 *Mixtures*

Matter is usually found in mixtures of pure substances rather than in their pure form. Mixtures are classified under two criteria: homogeneous or heterogeneous. In homogeneous mixtures, the parts of the mixture are indistinguishable. Homogenous mixtures are also called solutions. In heterogeneous mixtures, the different parts are clearly distinguishable from each other. (Zumdahl and Zumdahl 2014)

2.2.8.3 *The Mole*

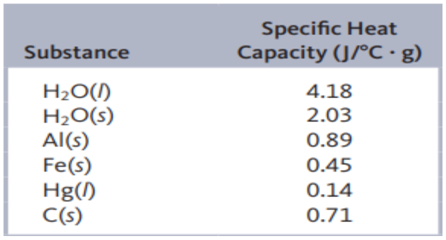
A mole is defined as the mass of an element being equal to its atomic mass in grams. Using moles is helpful because it facilitates the measure of atoms. Moles are used when measuring large amounts of small quantities, like atoms. (Zumdahl and Zumdahl 2014)

2.2.8.4 *Volatility*

Volatility describes the effortlessness of a substance to change into its gaseous state. A substance with higher volatility will turn into a gas more easily than a substance with lower volatility. (Zumdahl and Zumdahl 2014)

2.2.8.5 *Specific Heat Capacity*

Specific heat capacity measures the amount of energy required to raise a single gram of a substance by one degree Celsius. Water has the highest heat capacity of any liquid. The units for specific heat capacity are in joules/ºC·grams. Joules is the energy unit most commonly used in the SI system. (Zumdahl and Zumdahl 2014)



Substance	Specific Heat Capacity (J/°C · g)
$H_2O(l)$	4.18
$H_2O(s)$	2.03
$Al(s)$	0.89
$Fe(s)$	0.45
$Hg(l)$	0.14
$C(s)$	0.71

Figure 2-4: Specific Heat Capacities of different elements and compounds. Water is shown to have a significantly higher specific heat capacity than other elements. (Cengage Learning 2014)

2.2.9 Methods for Desalination

Although there are several ways to desalinate water, commercially desalinated water is produced by membrane filtration or thermal distillation. Membrane filtration, also known as Reverse Osmosis or RO, is the most prevalent technology used as it is is cheaper and produces less waste brine. Currently, RO accounts for 69% of the desalinated water in the world (Simon 2019).

2.2.9.1 *Distillation*

Distilling for desalination involves heating saltwater in a container. Water is more volatile than salts and other contaminants, and evaporates at relatively low temperatures. Once the water vaporizes, it is cooled so that it condenses back into a liquid state. The salt and other contaminants are left behind in the container that the saltwater was initially heated in. (Zumdahl and Zumdahl 2014)

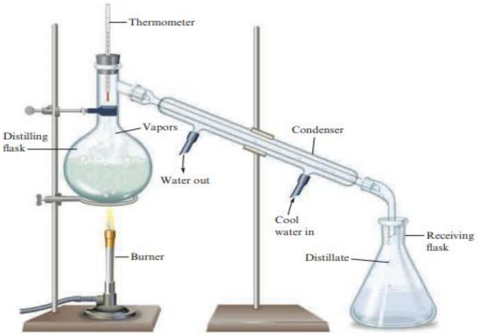


Figure 2-5: Simple Distillation Lab Equipment (Cengage Learning 2014)

2.2.9.2 *Reverse Osmosis or Hyper filtration*

Reverse Osmosis is when salt water is forced through a filter. The filter is small enough so that salt particles are unable to pass through, but water molecules can pass through. This process is used in over half of desalination industrial plants across the world (Reeves, 2018). Reverse Osmosis is also extremely expensive because it requires a high amount of energy to force the water through the filter (Robbins, 2018).

2.2.10 Materials

The Oxford dictionary defines a material as "a substance that things can be made from". There are many considerations many things to consider when choosing what material to use, for a project, such as "considerations of aesthetic appeal and initial and ongoing costs, life cycle assessment considerations (such as material performance, availability and impact on the environment) and the ability to reuse, recycle or dispose of the material at the end of its life" (Level 2020). In this project, specific heat capacity will be an important factor in choosing materials. Specific heat capacity is "the quantity of heat gained or lost when a given mass of a substance is warmed or cooled; the equation for specific heat capacity is q(heat transferred in joules)=C(specific heat capacity) * m(mass of substance) * ΔT(change in temperature)" (Kotz 2003). Weight is a consideration to consider when choosing a material. Weight will be evaluated in grams/mol, which is "the amount of substance that contains as many elementary entities (atoms, molecules, or other particles) as there are atoms in exactly 12g of the carbon-12 isotope" (Kotz 2003).

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2.2.10.1 *Aluminum*

Aluminum has a specific heat capacity of 0.897 J/g*K (Kotz 2003). Aluminum is an elemental metal, which is lightweight at roughly 27g/mol. Aluminum is used in construction because of its' high strength to weight ratio, low transportation costs, and corrosion resistance (The Constructor 2020). Aluminum costs $1,773.09 per metric ton or $1.77 per kilogram (Metalary 2020).

2.2.10.2 *Copper*

Copper has a low specific heat capacity of 0.385 J/g*K. Copper is a metal, which weighs approximately 64g/mol. Copper is useful in construction because it is "soft, malleable, ductile metal with high thermal and electrical conductivity and good resistance to corrosion due to the protective patina that forms on its surfaces" (Designing Buildings UK 2020). Copper costs $6,031.21 per metric ton or $6.03 per kilogram (Metalary 2020).

2.2.10.3 *Steel*

There is a variety of steel because it is an alloy. The encyclopedia of Britannica states that "steel is an alloy of iron and carbon in which the carbon content ranges up to 2 percent". Steel has a specific heat capacity that ranges from 0.460-0.510 J/g*K (Kotz 2003). The average molar mass of steel is approximately 56g/mol (Kotz 2003). Steel is favored in construction because of durability, fire resistance, easy maintenance, and relative environmental friendliness. Steel is $1.20 per pound or approximately $2.64 per kilogram.

2.2.10.4 *Plastics*

There are many benefits to using plastics in construction including its chemical resistance, electrical insulation properties, humidity control, and easy maintenance (The Constructor 2016). There are many different types of plastic, but they all have similar uses. Plastics used in thermal insulation are expanded polystyrene, expanded polyvinyl chloride (PVC), foamed urea formaldehyde, foamed phenol formaldehyde, foamed polyurethane, and expanded ebonite. Plastics used in water drainage and plumbing are polythene, polypropylene, non-plasticized PVC, and acrylic resins. The weight of plastics greatly varies, but they are considered to be relatively lightweight (The Constructor 2016). Plastics also vary in price but are on the cheaper side of materials ranging from $0.05-$0.15 per pound.

2.2.10.5 *Glass*

The encyclopedia of Britannica states that glass is made from sand with high silica concentration, that is then melted down and crystallized. There are many different types of glass, all of which have different purposes. Glass can be specialized to withstand heat, but not all glass has the capability to do so (Britannica). Glass that can be used in heating environments needs to have a high expansion coefficient, an example of glass with a high expansion coefficient is borosilicate glass (Britannica).

2.2.11 Heat Sources

A heating element is needed to distill water. Distilling water is the process of using evaporation to clean water. In this case, the distilling process is being used for desalination. Desalination is the process of removing salt from water. The physics definition for heat in the oxford dictionary is "heat seen as a form of energy that is transferred from one object or substance to another as a result of a difference in temperature".

2.2.11.1 *Electrical*

There are many approaches to heating water through electricity. One method would be to use a hot plate. Through an Amazon search of hot plates, one can find prices ranging from $22-$180. There is the question about reliability with some of the cheaper models. However, the Duxtop 1800W Portable Induction Cooktop Countertop Burner on Amazon is $50, has good reviews, and is aesthetically pleasing.

Hot plates are not the only method of electrically heating water. There are also immersive water heaters. An immersive water heater is essentially a heating element placed directly into the water. On mazon there are several immersive water heaters varying in price. The more expensive immersive water heaters can handle more wattage, therefore heat up more water.

2.2.11.2 *Solar*

Solar energy can be an effective way to evaporate water for distillation. In Dr. McCluney's article about solar distillation, he explains how solar distillation happens naturally, but water isn't collected. In order to take advantage of this natural process, Dr. McCluney suggests to place a cool surface above the body of water, that will be distilled. Another approach Dr. McCluney suggested, is to expediate this process by placing a dark surface underneath the water. A dark surface underneath the water would cause it to heat up rapidly. The benefit of using the sun as a heating element, is that the sun is free. A downside to using the sun, is that Humboldt county is continually overcast, and this overcast environment is the location for the desalination device.

2.2.11.3 *Fuel*

There are many fuel-based burners that can be used to heat water. The most commonly used fuel-based burner is a Bunsen burner. A Bunsen burner is the typical burner used for chemistry experiments. One requirement for the use of a Bunsen burner, is that there be a natural gas line for fuel.

In the absence of a natural gas line, one could use a butane or propane fueled camping stove. This does require one to buy and refill the butane or propane. Which would add extra increase costs to the client and perhaps introduce new risk factors such as fire hazard and carbon dioxide and carbon monoxide exposure in indoor environments.

3 Alternative Solutions

3.1 Introduction

The purpose of this section is to provide information on the brainstorming process and potential designs created. Nine alternative solutions were generated with the specifications and constraints of the client in mind. The different solutions are described along with a visual representation of the alternative.

3.2 Brainstorming Process

Our team conducted two brainstorming sessions, one being 30-minutes long, and a second being 7-minutes long. In our 30-minute session, team members collected ideas falling within categories of energy source, condenser type, heating element, and container shape. This session had additional commentary and analysis of each idea after it was shared. In our 7-minute brainstorm, we followed a different approach where team members all shared ideas one after another until the session ended.

3.3 Designs

The purpose of this section is to display all of the designs that were generated. The specifics of the design are discussed along with whether or not they would meet criteria.

3.3.1 The Bain-Marie

The Bain-Marie is constructed with an entirely electric design including a boiling flask as the container, a rubber stopper with tubing as the condenser, and a bain-marie as the heating source.

The boiling flask containing the saltwater mixture is partially submerged under the hot water in the bain-marie and held in place by a clamp attached to the outer rim of the structure. The hot water bath gradually causes the solution in the flask to evaporate through the rubber stopper leading into a separate container (i.e. a beaker), where the distilled water would be collected. The salt would remain contained within the boiling flask.

The all-electric and efficacy constraints would be maintained, but the aesthetics and educational value criteria may be compromised with the use of a water bath and rubber tubing.

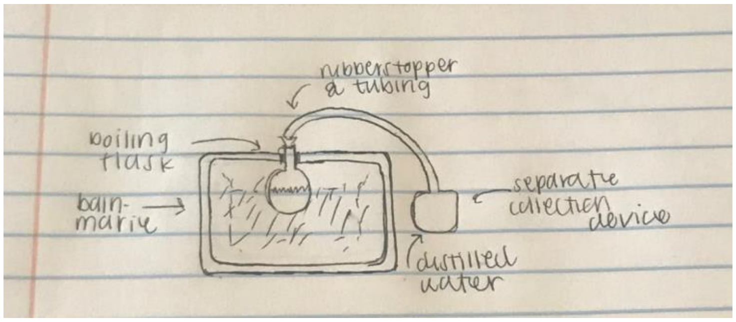


Figure 3-1: Alternative Solution #1 Bain Marie (Photo Credit: Angel Ortiz)

3.3.2 The Salty Kombucha

The Salty Kombucha is constructed out of an entirely electric device with a mason jar as the container, an airlock bubbler as the condenser, and an immersive water heater as the heating source. The mason jar containing the saline solution is placed in a hot bath with the submersible water heater. Attached to the mason jar lid is an airlock bubbler maintained in place by a rubber stopper. As the mason jar is warmed by the bath, the solution would evaporate and the clean distilled water is trapped in the bubbler. The mason jar contains the remaining salt crystals. Both the mason jar and airlock bubbler are made of glass.

The electric, efficacy, and educational value constraints would be maintained but, the safety criteria may be compromised with the use of the immersive heating device.

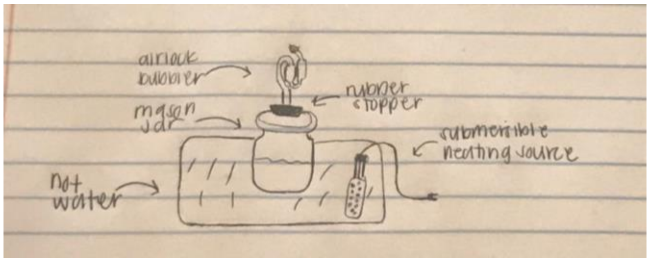


Figure 3-2: Alternative Solution #2 The Salty Kombucha (Photo Credi:t Angel Ortiz)

3.3.3 Solar/Electric Hybrid Solution

The Solar/Electric Hybrid incorporates the use of solar power and an electric heating element. Solar desalination is more environmentally friendly but tends to be unreliable in Eureka with the frequently overcast conditions found on the North Coast. This design features a wooden frame roughly 60 x 30 cm with legs. The frame is lined with a custom-built metal trough to hold the salt water solution. The trough is powder coated black to absorb solar radiation and resist corrosion. The trough is topped with a 20 cm high glass pyramidal condensing dome. The dome allows sunlight to heat the water and allows for viewing of the condensation as the water evaporates. The vaporized water condenses on the cold glass of the dome and runs down into collection gutters installed on the inside of the trough. The water then runs through a drain channel to a collection vessel. There is also a UL listed submersible hot water heater element installed inside the pan. The element is mounted to a waterproof junction box and the wiring come out of the bow is waterproofed with heat shrink tubing, then wired to a grounded A/C plug. The water heater element is used when there is not enough solar gain to cause vaporization.

This solution would meet the criteria of aesthetics, educational value and power consumption but the efficacy would be compromised when using the electric option because this design prevents the heating element from being in contact with the total volume of water thus eliminating the possibility of evaporating the water all the way to salt crystals. It would also run the risk of compromising the safety of the device, even though steps are taken to prevent water contact with the electrical circuit, we cannot be sure that the salt water would not compromise this circuit over time.

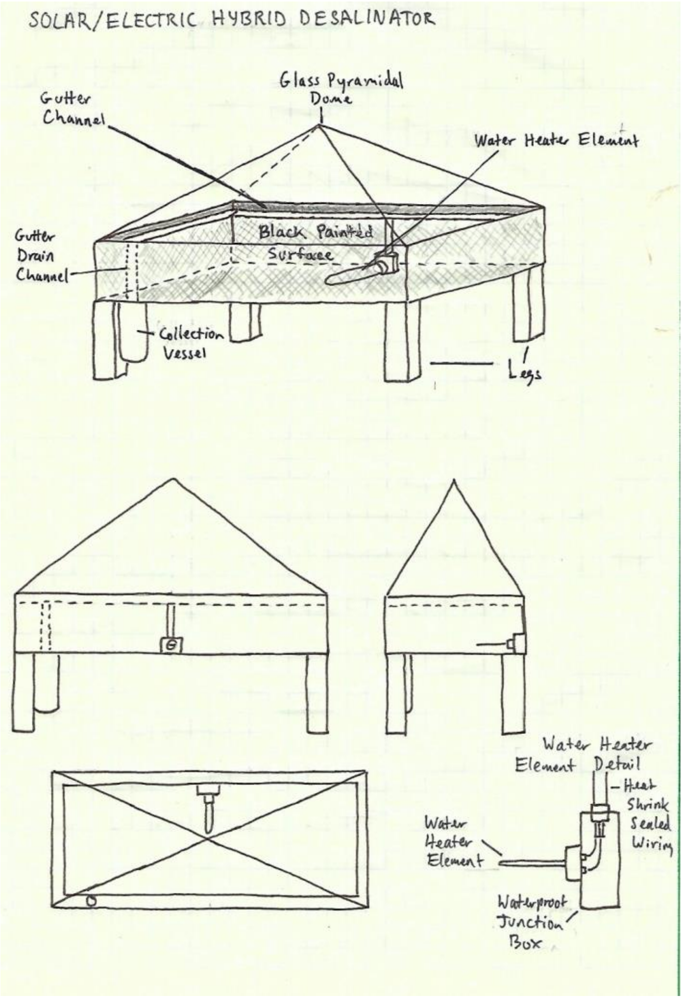


Figure 3-3:Alternative Solution #3 Solar/Electric Hybrid Solution (Photo Credit Chris Koier)

3.3.4 Fully OTS Desalination Device

The Fully OTS Desalinator design attempts to fulfill all the design criteria and specifications through the use of readily available" off the shelf" consumer items. The base of the desalination device is a commercial grade griddle with adjustable temperature control and a large volume grease trap (Yesco 14" Griddle). A glass dome intended for upscale catering or parties sits on the grill surface and acts as a condenser (Cake Dome). Under the dome, also on sitting on the surface of the griddle are 100 ml Erlenmeyer flasks (Flasks) filled with saline solutions made by the 7th graders. The griddle heats the solution in the flasks, the dome condenses the vapor. The purified water then runs over the surface of the griddle to collect in the grease trap. This system would require shims under the back legs of the griddle to increase efficiency draining the water into the grease trap. It may also need metal shims under the dome to prevent a hydrostatic seal forming between the dome glass and the griddle surface.

This design meets much of the design criteria: educational value, safety, efficacy. It may not meet the aesthetics criteria and the cost of the required parts is roughly $350. That cost leaves little margin for other costs associated with building the design.

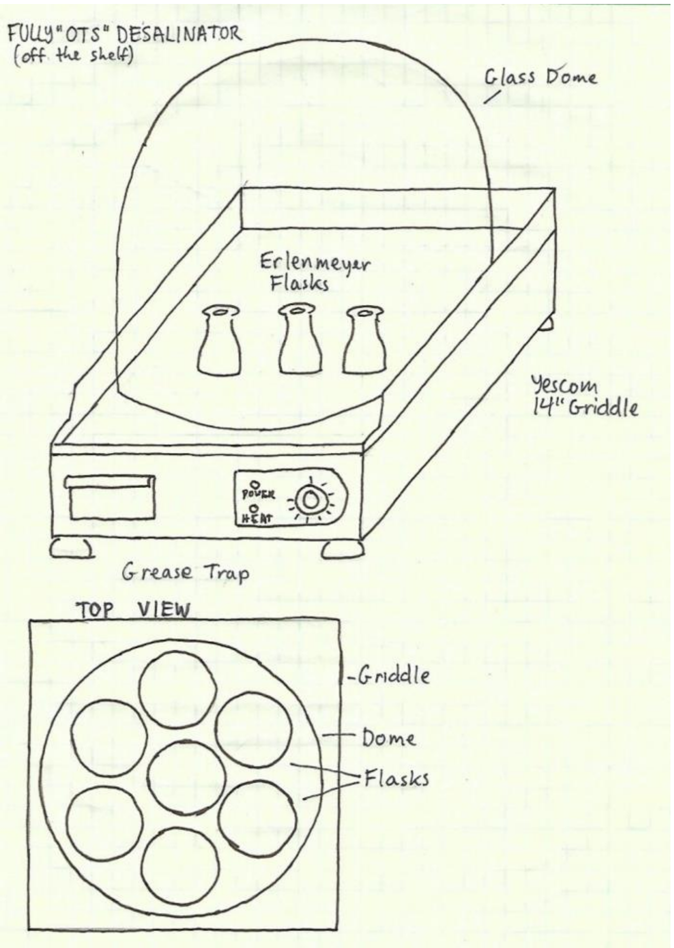


Figure 3-4:Alternative Solution #4 Fully OTS Desalinator (Photo Credit Chris Koier)

3.3.5 The Falcon- Electric Desalination Device

The Falcon- Electric Desalination Device is inspired from the mascot of Zane Middle School, the falcon. The device has a falcon head shaped dome. This falcon dome is built this way to help guide water to the collection bin. Inside the falcon dome there is glass lipping which is also put in place to help guide the water to its desired destination. The glass dome is fit so that the hot plate buttons can be used and monitored, but the hot surface will not be available for the students to injure themselves on. In the midsection of the side with the hotplate controls there is a double door. This door is so that one can place the beakers inside. The doors will be held tight with magnets. The frame of The Falcon is made of wood. It is hollow on the inside. On the side with the collection bin there is a metal "slide" that feeds into the collection bin.

This would meet the criteria of efficacy. However, this may fall out of the constraint for the cost criteria. The special cut glass might get expensive. This project would most definitely meet the criteria for educational value. It would easily be seen by 6 students from at least 6 feet. Lastly this would fit the criteria for aesthetic value. The falcon shape dome is also representative of Zane middle school mascot.

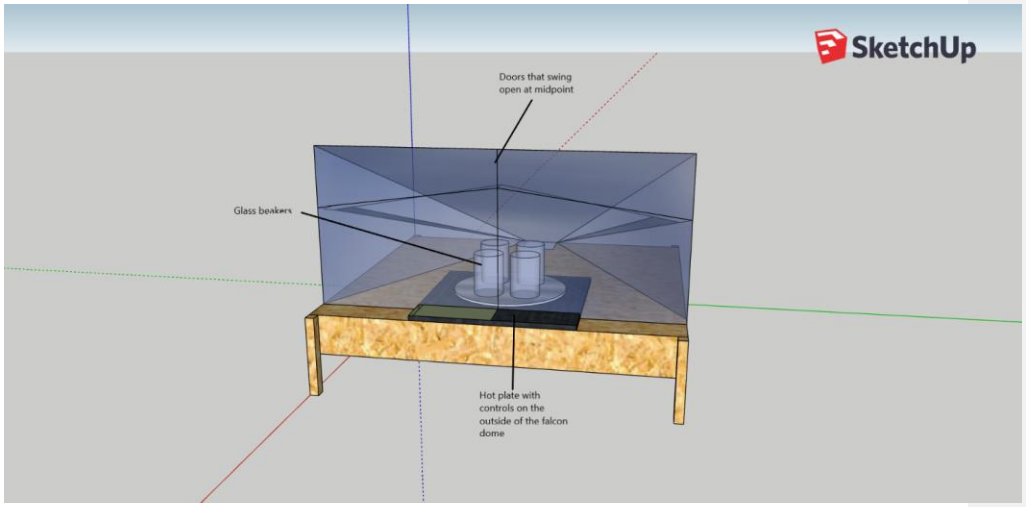


Figure 3-5:Alternative Solution #5 The Falcon- Electric Desalination Device (View 1) (Design Credit Amanda Ratcliff)

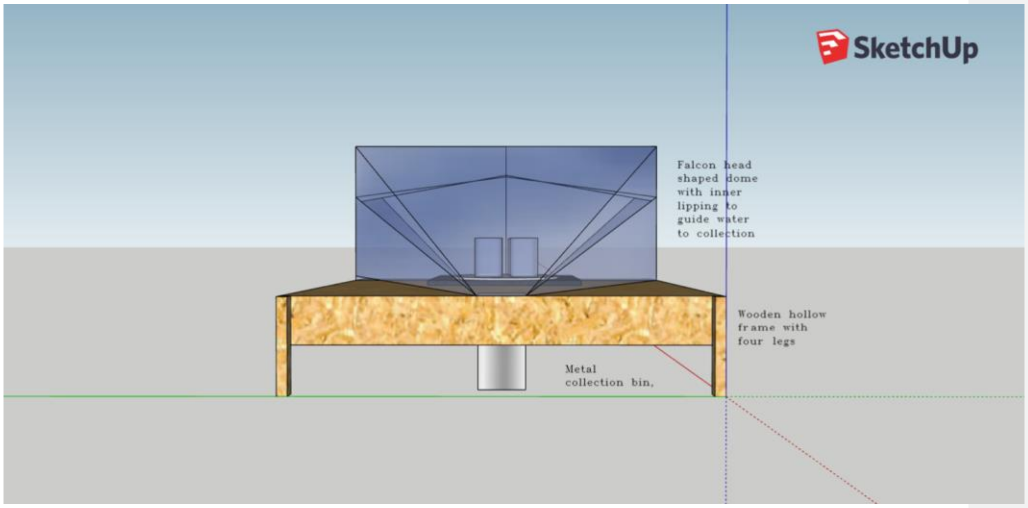


Figure 3-6: Alternative Solution #5 The Falcon- Electric Desalination Device (View 2) (Design Credit Amanda Ratcliff)

3.3.6 The Muffin Man

The Muffin Man utilizes an elevated platform with a pyramid shape that would act as a condenser once the liquid is evaporated. The heating element for this design is a hot plate placed at the base of the structure. The vessel that will hold the saline solutions that are heated is a muffin pan. This allows multiple locations for salt crystals to be formed. The pyramid is made with glass that allows viewers to see liquid condense on the panels. Wooden support beams elevate the pyramid. Once the water evaporates it falls into a gutter collection system that is attached to a drainage hose. The water flows through the drainage hose into another collection vessel. Transparent glass windows are built on all four sides of the structure. One of the windows is attached to a hinge that allow it to be opened. Magnets are attached to the support structure to secure the openable window in a closed position.

This device would meet the educational and aesthetics criteria because it would be viewable from all sides. Cost criteria may not be met because glass may prove to be a better condenser option instead of plastic, which run up the cost. Power consumption criteria would be met since heating device would utilize a safe commercial hot plate. Meeting safety criteria may be an issue because water may drip back onto hot plate, and the fragility of glass makes it less safe. Our efficacy criteria would be met because water would evaporate.

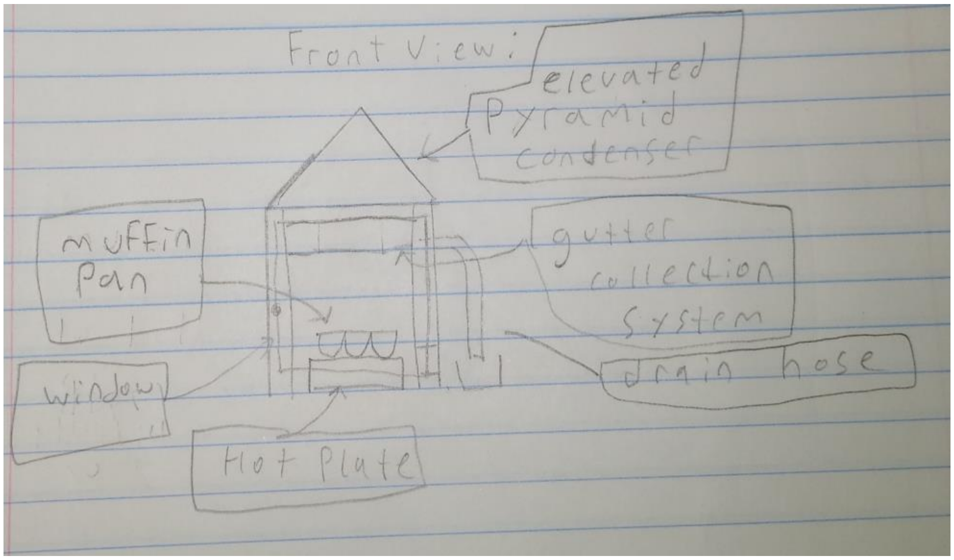


Figure 3-7:Alternative Solution #6 The Muffin Man (Photo Credit Brenden Chavez)

3.3.7 What's the Tea?

What's the Tea utilizes an elevated dome-shaped condenser. The initial vessel holding the saline solution is a metal cup. The metal cup sits on a base. The saline solution is first heated by a submersible water heater. Once the water is evaporated it travels up to the dome-shaped condenser and falls into a gutter collection system. The dome shaped condenser is elevated and held up by wooden supports. Once in the gutter collection system, the water flows through a drainage hose and into final collection vessel.

This device would meet educational criteria since it has many locations it can be viewed from, but may not fit the safety criteria due to the submersible water heater being exposed. Cost criteria may not be met because the glass rounded dome condenser would be very expensive to make. The aesthetics, power consumption, and efficacy criteria would be met.

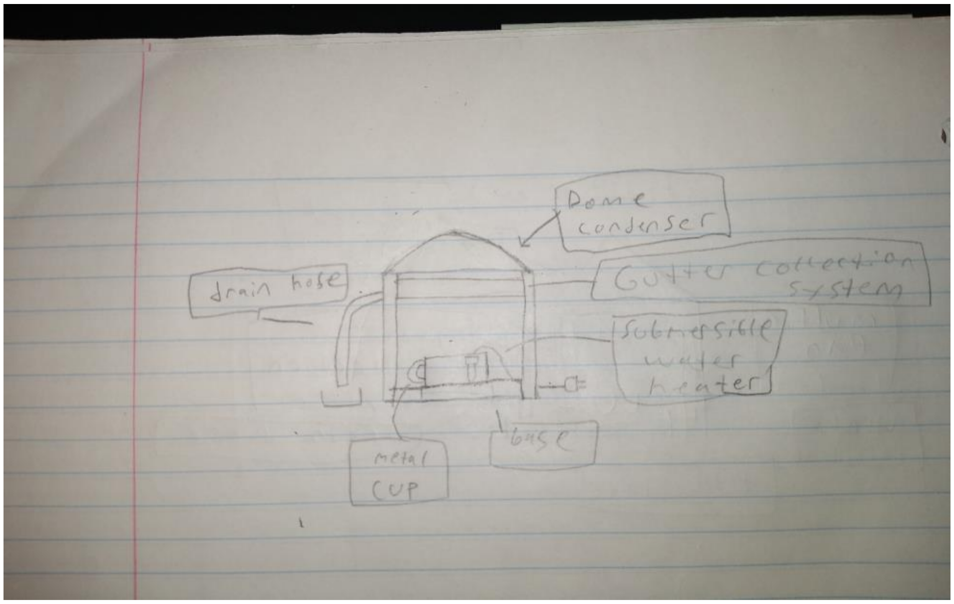


Figure 3-8:Alternative Solution #7 What's the Tea? (Photo Credit Brenden Chavez)

3.3.8 The Thorny Dragonborn

The Thorny Dragonborn gets its inspiration from the thorny lizard. The thorny lizard is a desert animal that gathers water in the desert by using spikes around its body. These spikes not only collect water but guide water to the animal's mouth. The spikes are attached to the inner cylinder. In the inner cylinder, there is a battery powered hot plate. This hot plate heats up four beakers of hyper saturated saline solution. Once the water turns to steam it rises to the top of the dome and then collect on the spikes. The water then trickles down to the bottom of the outer cylinder. There is a raised platform on which the hot plate rests on, so that it does not get wet.

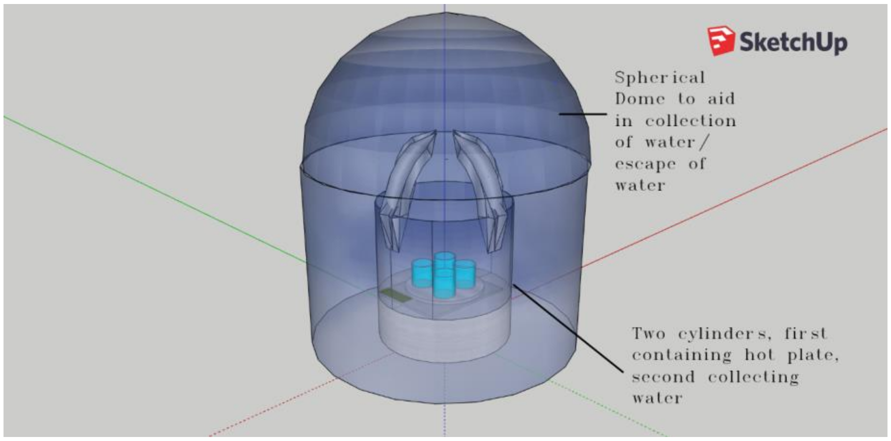


Figure 3-9: Alternative Solution #8 The Thorny Dragonborn (View 1) (Photo Credit: Amanda Ratcliff)

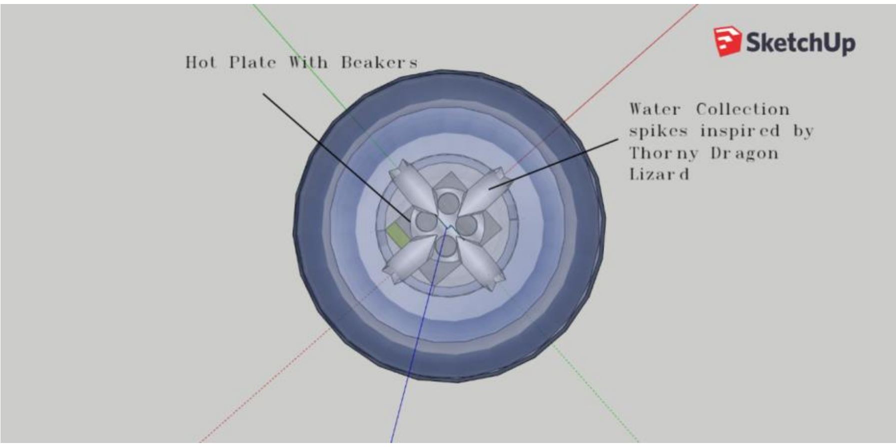


Figure 3-10: Alternative Solution #8 The Thorny Dragonborn (View 2) (Photo Credit: Amanda Ratcliff)

3.3.9 Lean with it Rock with it

The Lean with it Rock with it utilizes a lean-to design. The plexiglass condenser is where the lean-to design can be seen. A silicone heating pad is used to heat up the saline solutions. The saline solutions are going to be placed in 100 milliliter beakers. Foam walls will help to insulate device and make sure condensation is seen on the condenser. Once the water condenses it will drip down plexiglass condenser and into collection dish.

This design would meet all of the criteria.

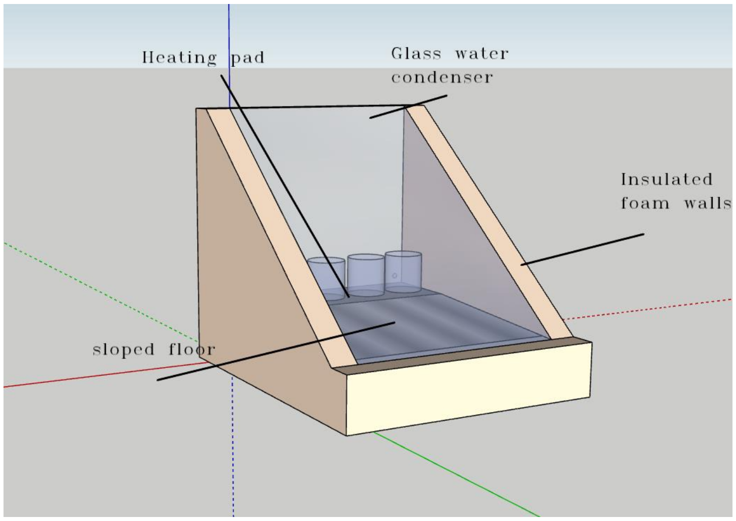


Figure 3-11: Alternative Solution #9 The Lean with it Rock with It (Photo Credit: Amanda Ratcliff)

4 Decision Process

4.1 Introduction

Section 4 describes the decision process. This section presents all of the Alternative solutions and selects a final design through the use of the Delphi Matrix. In section 4.4, the results of the Delphi matrix are generated to create the best fit solution to the constraints set forth by the criteria.

4.2 Criteria

This subsection defines our criteria. The definitions of our criteria define how well an alternative solution will work for its desired intention.

Efficacy: The device should separate water from salt. Thus, producing salt crystals, and clean water.

Aesthetics: The desalination device should look aesthetically pleasing to children. The device should also be as aesthetically pleasing as other scientific objects in the room, such as the taxidermy duck showcase.

Cost: The cost out of pocket should not exceed the budget defined in section 2.

Power Consumption: The desalination device must operate on a 15-amp 120v circuit. It should use the least amount of electricity possible. So that it is better for the environment, the school's budget, and the safety of the device.

Educational Value: The main purpose of this device is to educate kids on desalination. Therefore, this device should not only desalinate water, but have the process be observable over an extended period of time.

Safety: While other criteria may be important, there is nothing more important than the safety of the children who will be using this device. The desalination device should be as safe as any other electrical device in the classroom.

4.3 Solutions

The following list is comprised of the alternative solutions from Section 3.

The Bain-Marie

The Salty Kombucha

Solar/Electric Hybrid Solution

Fully OTS Desalinator

The Falcon-Electric Desalination Device

The Muffin Man

What's the Tea?

The Thorny Dragonborn

Lean With It Rock With It

Details of each alternative solution are given in Section 3.

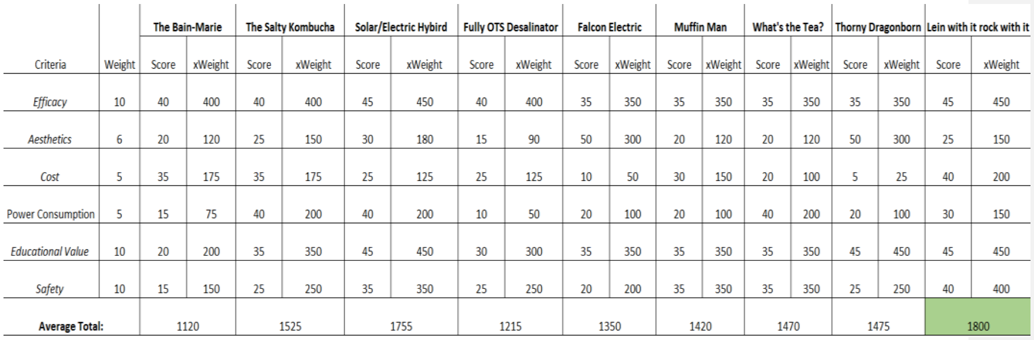
4.4 Decision Process

The Delphi method is used for our decision-making process. This method employs a Delphi matrix to evaluate each alternative solution in relation to the established weighted criteria. The criterion were discussed in section 2 and are relisted in table 4.1 below with their relative weights on a 1-10 scale. These weights were evaluated by the group and confirmed through client input. These criteria weights are multiplied by a 0-50 rating for each alternative design solution in table 4.2.

Table 1: Table of Criteria Weights.

Efficacy	10
Aesthetics	6
Cost	5
Power Consumption	5
Educational Value	10
Safety	10

Table 2: Delphi Matrix table.



		The Bain-Marie		**The Salty Kombucha**		**Solar/Electric Hybird**		**Fully OTS Desalinator**		**Falcon Electric**		**Muffin Man**		**What's the Tea?**		**Thorny Dragonborn**		**Lein with it rock with it**	
Criteria	Weight	Score	xWeight	Score	xWeight	Score	xWeight	Score	xWeight	Score	xWeight	Score	xWeight	Score	xWeight	Score	xWeight	Score	xWeight
Efficacy	10	40	400	40	400	45	450	40	400	35	350	35	350	35	350	35	350	45	450
Aesthetics	6	20	120	25	150	30	180	15	90	50	300	20	120	20	120	50	300	25	150
Cost	5	35	175	35	175	25	125	25	125	10	50	30	150	20	100	5	25	40	200
Power Consumption	5	15	75	40	200	40	200	10	50	20	100	20	100	40	200	20	100	30	150
Educational Value	10	20	200	35	350	45	450	30	300	35	350	35	350	35	350	45	450	45	450
Safety	10	15	150	25	250	35	350	25	250	20	200	35	350	35	350	25	250	40	400
Average Total:		1120		1525		1755		1215		1350		1420		1470		1475		1800	

4.5 Final Decision

The Delphi method concluded that the design Lean with it Rock With it is best suited for a classroom desalination device. Safety was weighted one of the most important criteria. The use of a heating pad would make the desalination process slower and safer. Additionally, the use of a hot pad would entirely prevent a student from burning themselves, or significantly lessen that possibility, compared to other heating element options. The slow rate of the desalination process adds to the educational value, so the students can observe the process happen over time. The roof constructed from glass or plexiglass allows the students to watch the process happening, also adding to the educational value. We opted out of choosing a design with multiple sides made of glass, because of safety concerns with the glass breaking, and potential cost issues. Efficacy was deemed one of the most important criteria. The simple design of the solution will provide the best functionality as a comprehensive desalination device for the students.

5 Specification

5.1 Introduction

Section 5 of the document describes the desalination device chosen in section 4, the Lean with it Rock with it. This section includes a detailed description of the final design with instructions for the implementation and use of the design. The cost of supplies, labor, and predicted cost of maintenance are supplied in this section as well.

5.2 Description of solution

The Lean with it rock with it is the design that was selected to educate children at Zane Middle School. The desalination device has a wooden base. The walls of the device are made out of insulated polystyrene foam. The heating device is a silicone heat mat with an adjustable temperature. The location where the evaporated water will condense will be made out of plexiglass or glass, so the internal process can be viewed. Once the water has condensed it be collected into our catchment system where it can be disposed of.

5.2.1 The catchment system

The catchment system has a point positive design that encourages system maintenance. Point positive designs look ahead, and lead the user of a device or system to do a desired action. In this case the desired action is to clean out the collection tray. The collection tray will stick out an inch or so beyond the device, so that the volume and cleanliness of the water is visible to the user. The idea is that if the user sees that the device is getting dirty or might overflow, they will feel obligated to clean the device.

The collection tray will be made of a rust proof metal, in order to maintain its longevity. The tray will essentially function like a drawer without tracks. It will slide underneath the desalination device, and have a stopper, which makes it stop at the desired depth underneath the desalination device.

5.2.2 Condenser

At the top of the desalination device there will be a condenser. The condenser is where most of the water vapor will condense and then run down to be collected in the catchment system. The condensing location is going to be made of glass or plexiglass. Either of these materials will allow for easy viewing of the process. This is an integral part of the device since visibility supports the educational value criterion. The is condenser is 26.5” long, 15.5” wide and 1/8” thick. The condenser will be at a slope of 51.66° with the horizontal axis. Figure 5.1 below shows the condenser.

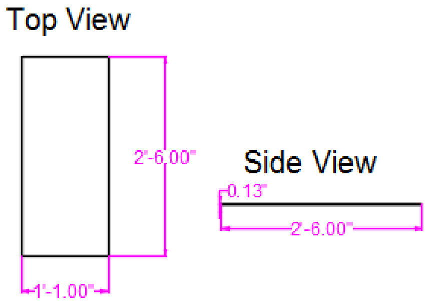


Figure 5-1 :Condenser CAD. Design by Brenden Chavez

5.2.3 The Heating Device

The heating component for the desalination device is comprised of three elements as depicted in Figure 5.2. At the top is a commercial ½ sheet pan made of aluminum. The beakers filled with salinated water will sit directly on top of this pan. Directly under the pan, is a silicone heat mat. This heating mat is 12.2in^2. It is 120V and 750W, delivering a total of 5.2 watts per square inch. The silicone mat is waterproof and quickly distributes heat evenly. Directly under the mat is another sheet pan with ceramic spacers. These spacers ensure good contact between the heat mat and the top pan.

The silicone heating mat is controlled by a thermostatic controller, a Ketotek STC 1000. The temperature controller supplies 110V of power and can maintain temperatures between –50 to 99 C. This device consumes less than 3W and its dimensions are 2.95 x 1.35 x 3.35 inches. A 2mm sensor probe is attached for reliable temperature monitoring This controller is built into the wooden frame, keeping the wiring safe and making it convenient to program the device.

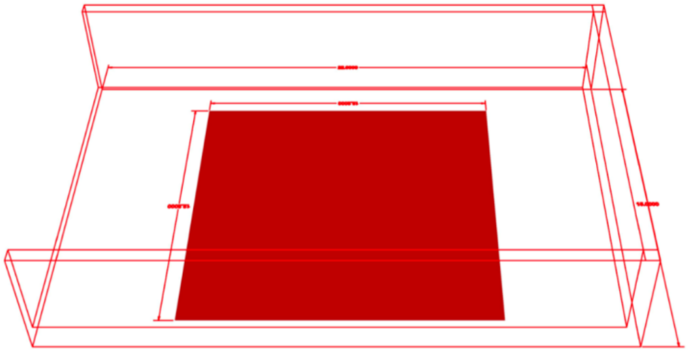


Figure 5-2: CAD drawing of heating element. Design by Angel Ortiz.

5.2.4 Insulated walls

The walls of the desalination device are constructed from extruded polystyrene foam. Extruded polystyrene or EPS is a construction grade insulation material suitable for use in wet environments. The EPS used in this project is 2” thick Owens Corning, Foamular 150. It has an R value of 10 and a compressive strength of 15 psi. It absorbs very little water, 0.03% by volume, and has low vapor permeability, 86 ng/Pa•s•m2. These physical material properties make it ideal for this desalination device. The high thermal resistance, low water abortion and low vapor permeability allows for most of the vapor condensation to occur on the condenser rather than the structural walls of the device. This maximizes visibility of the phase change from vapor to water meeting the projects educational goals. In addition to insulating the device and containing vaporized and condensed water, the walls of the device serve to support the condenser while still allowing it to be removed for access to the surface of the heating device and the beakers containing the saline solution. The material’s rigidity and compressive strength easily support the weight of the condenser.

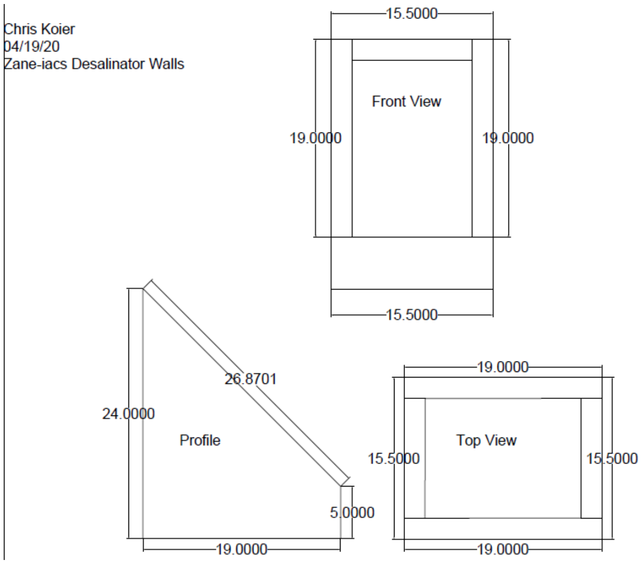


Figure 5-3: Desalinator Walls CAD. Design by Chris Koier.

5.3 Design Costs

The design costs indicate the number of hours that Team Zane-iacs invested to design and create this desalination device for Zane Middle School. A total of 28.25 hours were spent on this design project. The majority of the design hours were spent in Phase 5. Figure 5.4 represents the distribution of hours that went into this project.

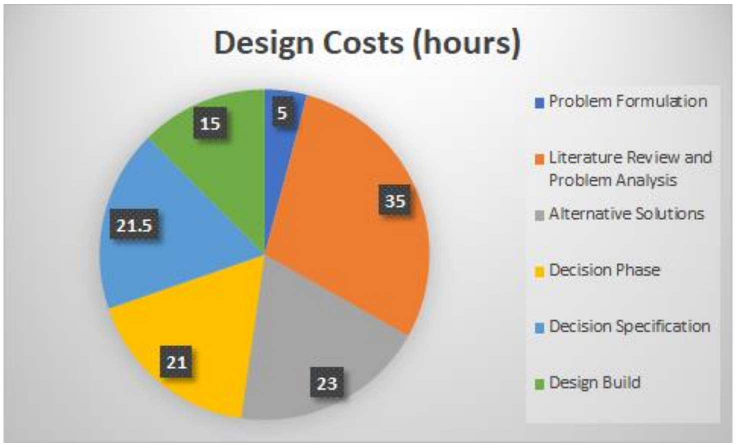


Figure 5-4: Design costs in team labor hours. Credit: Chris Koier

5.3.1 Materials Costs

Table 5-1 indicates the costs of materials used in the construction of the desalination device. The total amount spent to construct the project was $0. Due to the Shelter in Place quarantine many materials had to be scavenged from team members homes and were essentially free so the actual project costs are much lower than projected costs would be if this project had been built from purpose bought materials. The projected costs would be $0. Figure 5.5 below shows the materials costs.

Materials Costs					
Materials	Use	Quantity	Retail Cost each	Total	Build Cost
Commercial Sheet Pan	Heating Plate	2	$3.89	$7.78	$0.00
1x12 pine board	Desalinator Base	1	$19.70	$19.70	$0.00
Screws	Fasteners	12	$0.10	$1.20	$0.00
EPS Foam Insulation	Insulative Walls	1	$27.37	$27.37	$0.00
Silicone Heating Mat	Heat Source	1	$39.99	$39.99	$0.00
Thermostatic Controller	Thermostat	1	$15.99	$15.99	$0.00
Glass cutter	Cutting glass (prototype)	1	$5.99	$5.99	$5.99
Channel Trim	Edging glass (prototype)	2	$8.59	$17.18	$17.18
Locknuts	Securing drain spout	1	$1.39	$1.39	$1.39
Furnace Cement	Gluing ceramic tile	1	$5.99	$5.99	$5.99
Ceramic tiles	Heating pad base	8	$3.19	$25.52	$0.00
Plexiglass sheet	Condensing Dome	1	$13.99	$13.99	$13.99
Weather seal	Sealing Plexi	1	$3.99	$3.99	$3.99
Caulk	Sealing Walls	1	$7.99	$7.99	$7.99
Threaded Rod	Sealing Dome	3	$4.49	$13.47	$4.49
1x2x8 Pine board	Frame for walls	1	$2.99	$2.99	$2.99
Rubber weather strip	Seal for Frame	1	$7.59	$7.59	$7.59

Misc. Nuts and Bolts	For threaded rod	1	$3.24	$3.24	$3.24
		Total		$221.36	$74.83

Figure 5-5: Materials costs. Credit: Chris Koier

5.3.2 Maintenance Costs

Maintenance costs for Lean With it Rock With it will be minimal. Labor hours will be limited to set up and clean up. Operational costs are based on power consumption per use with the following formula: 750 W*(0.001 W/kWh) *24 hours*$0.24488/kWh. Total operational costs are shown in figure 5.6 below.

Maintenance and Operation				
Maintenance Costs			Operational Costs	
	Time (minutes)	Labor Rate (at $25 per hour)	Power Consumption (watts)	750
Setup	10	Labor rate per minute	Average commercial electric rate (per kWh)	$0.2450
Cleaning	20	$0.42	Operating costs (per day)	$4.41
Total	30			
		Total labor cost per use	Estimated per use cost	
		$12.50		$8.82
Total estimated cost per use		$21.32		

Figure 5-6: Maintenance Costs. Credit: Chris Koier

5.4 Instructions for Implementations and Use

The desalination device is intended to be used on a countertop with electric power. First remove the walls and condenser. Fill the beakers with a saline solution. Place full beakers on the heating pad. Replace the cover, check for alignment of seals and plug in the device. Check that the temperature controller lights are on. The device should take 1-2 days to complete desalination. Once desalination is complete. Remove the beakers, and clean the collection vessel. The collection tray sticks out slightly, so the user will be able to see if it might overflow, and the vessel’s state of cleanliness. The beakers should have salt crystals in them. If larger salt crystals are desired use non-iodized salt, and make it a hyper concentrated solution. One can also make the salt crystals have fun colors by adding food coloring. The beakers may be cleaned by adding water and soaking. Alternately, the crystals can be scraped out and then rinsed to remove any residue. However, be sure to use care when scraping crystals out the beakers to avoid breakage.

5.5 Results of Prototyping

5.5.1 Introduction to prototyping

Prototyping is a way to test how well design options meet criteria. Four prototypes were created: one to test the functionality of the heating element, one to test external aesthetic, one to test the internal design and one to test the functionality of the catchment system.

A unique challenge to this design project was the advent of the COVID-19 virus. A Shelter in Place order was implemented by the state of California just before prototyping could begin. The team members were unable to meet and had more limited access to prototyping materials. Simple prototypes often of found objects were used as a work around in this situation.

5.5.1.1 *Heating Element Prototype*

To prototype the function of the heating device, a 12 x 12 in. silicone heating pad, a Pyrex glass measuring cup, and a stainless-steel container, were utilized to evaporate the water as shown in Figure 5.7.

Figure 5-7: Prototype of the heating element. Photo credit: Chris Koier.

In the test, the stainless-steel container modeled the sheet pan between the heating pad and the beakers. The heating mat was set to 40 C. The first observation was that heat was efficiently transferred from the mat to the water, the water was warm to the touch. The water gradually evaporated and was completely evaporated in ~ 48 hours. A film of naturally occurring minerals in the water sample used was observed in the bottom of the measuring cup.

5.5.1.2 *Overall Aesthetics Prototype*

To prototype the aesthetic of the device as a whole, a tea box a piece of plastic wrap was utilized as seen in Figure 5.8. This simple test solidified the use of a lean-to condenser in our final project.

Figure 5-8: Figure 5 8: Prototype of the aesthetics of the entire device. Photo credit: Brenden Chavez

5.5.1.3 *Internal Design Prototype*

To prototype the internal design of the device, a cardboard box was modified to create all the components of the device as seen in Figure 5.9.

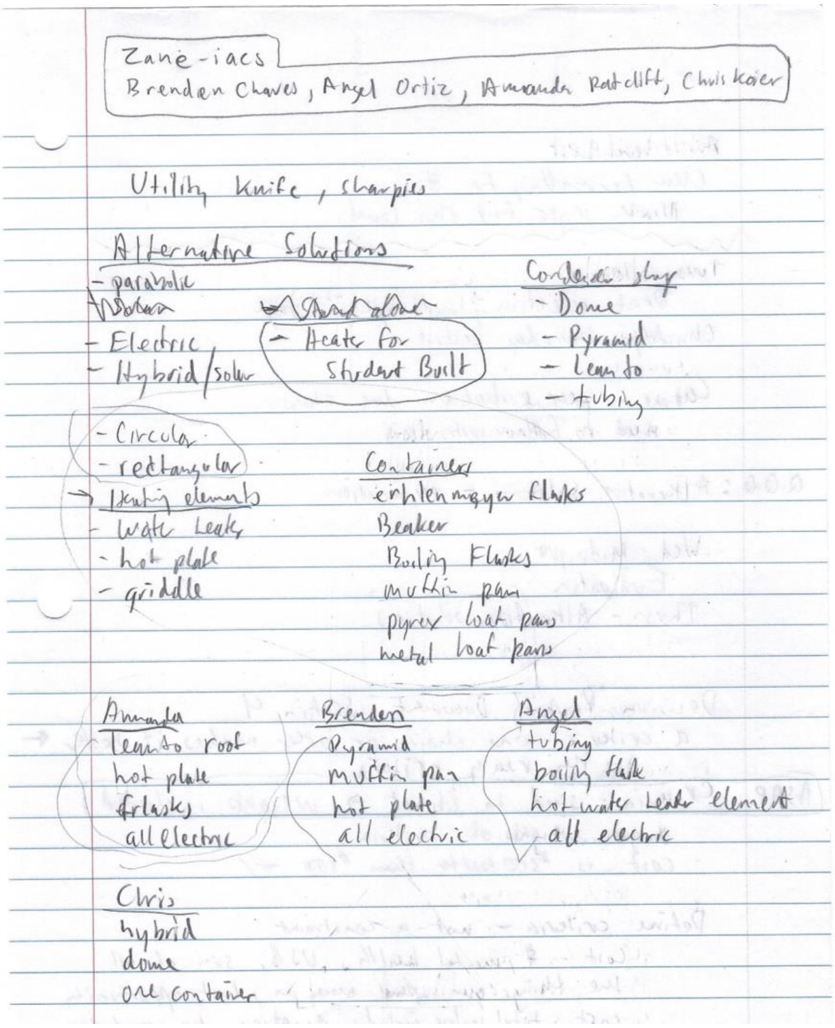
Figure 5-9: Model of the internal view of the device. Photo credit: Amanda Ratcliff.

This prototype also tested the viability of a rear access panel. It was easy to open and move the beakers in and out of the of the model. It also included the collection dish which demonstrated the ease of removal and emptying. This prototype provided a realistic model of internal dimensions and functionality.

6 Appendix

6.1 Appendix A: Brainstorm Documents

The following images are to document our brainstorming sessions as referenced in Section 3, Alternative Solutions.



Zane-iacs
Brenden Chaves, Angel Ortiz, Amanda Ratcliff, Chris Kaier

Utility knife, sharpies

Alternative Solutions
- parabolic
- ~~Solar~~
- Electric
- Hybrid/solar

~~Stand alone~~
- Heater for Student Built

Condenser shape
- Dome
- Pyramid
- Lean to
- tubing

- Circular
- rectangular

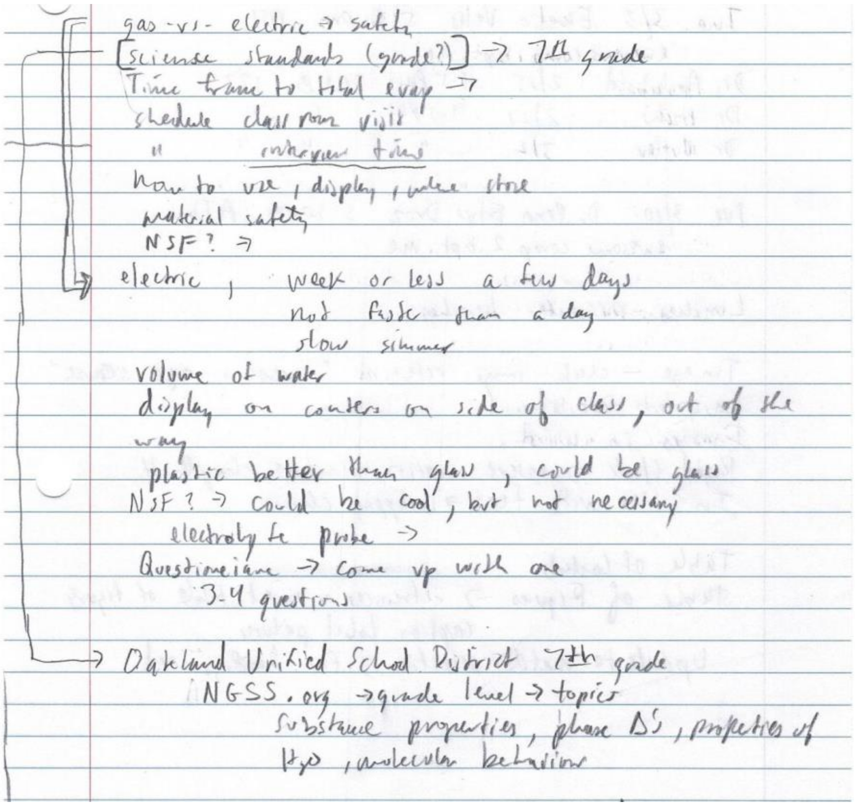
→ Heating elements
- water heater
- hot plate
- griddle

Containers
erhlenmeyer flasks
Beaker
Boiling Flasks
muffin pan
pyrex loaf pans
metal loaf pans

Amanda	Brenden	Angel
Lean-to roof	Pyramid	tubing
hot plate	muffin pan	boiling flask
flasks	hot plate	hot water heater element
all electric	all electric	all electric

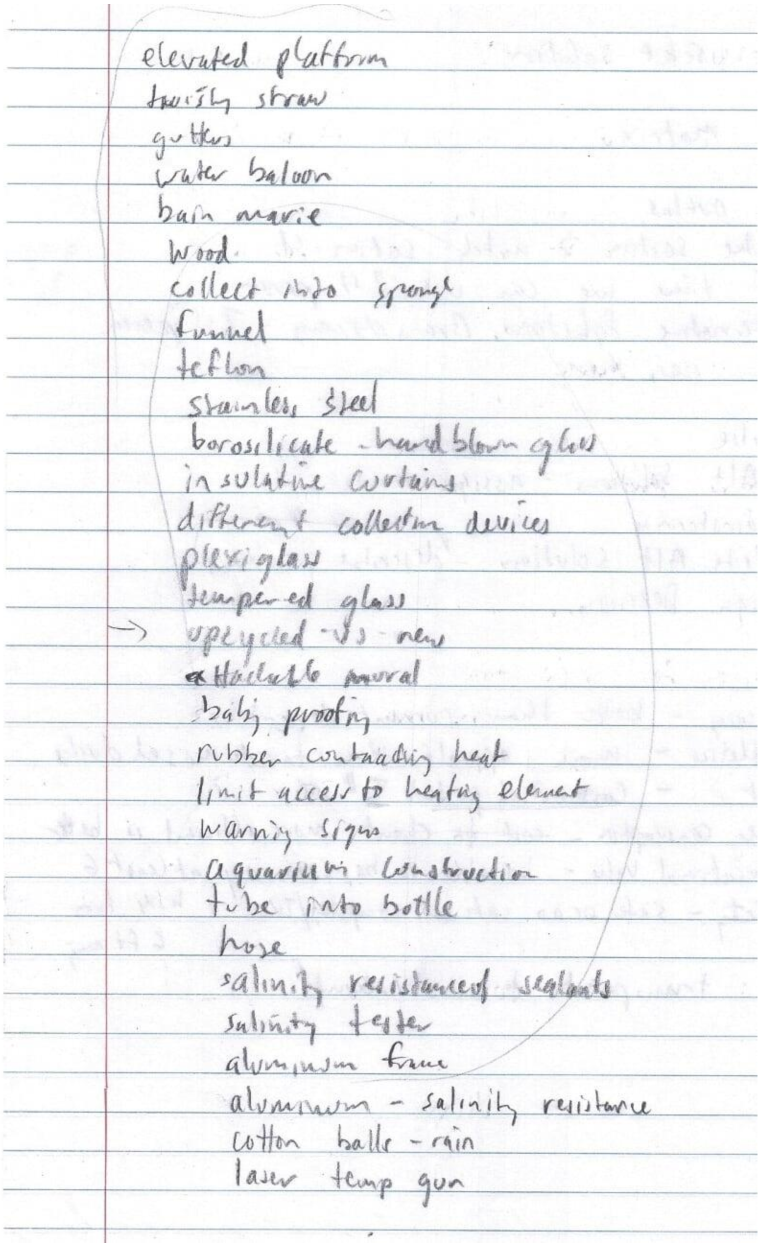
Chris
hybrid
dome
one container

Figure 6-1: Notes depicting different design components.



gas -vs- electric → safety
[Science standards (grade?)] → 7th grade
Time frame to total evap →
schedule classroom visit
" interview time
how to use, display, where store
material safety
NSF? →
electric, week or less a few days
not faster than a day
slow simmer
volume of water
display on counters on side of class, out of the way
plastic better than glass, could be glass
NSF? → could be cool, but not necessary
electrolyte probe →
Questionnaire → come up with one
3-4 questions
→ Oakland Unified School District 7th grade
NGSS.org → grade level → topics
substance properties, phase Δ's, properties of H_2O, molecular behavior

Figure 6-2: Notes demonstrating alternative design options.



elevated platfrom
twisty straw
gutters
water baloon
bain marie
wood
collect into sponge
funnel
teflon
stainless steel
borosilicate - hand blown glass
insulative curtains
different collection devices
plexiglass
tempered glass
→ upcycled - vs - new
attachable mural
baby proofing
rubber containing heat
limit access to heating element
warning signs
aquarium construction
tube into bottle
hose
salinity resistance of sealants
salinity tester
aluminum frame
aluminum - salinity resistance
cotton balls - rain
laser temp gun

Figure 6-3: Notes from 5-minute all-ideas-out brainstorm session.

6.2 Appendix B: References

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