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The E in STEM

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### Major Project: Reflection

a. Since I could not do this project at school because of COVID restrictions, I substituted four of my family members and neighbors for my middle school students. Overall, I thought this engineering design challenge went pretty well, especially the first three stages (identifying the problem, brainstorming, and designing). I changed some of the procedure from that found in the *On the Moon Educators Guide*. I allowed my students to use as much cardboard and tubing as they wanted. My students could also attach the tubing to the cardboard however they wanted. I found that following the steps of the engineering design process, from identifying the problem and constraints to revising and making improvements, helped clarify and streamline the process of making the solar heaters. I also found that keeping track of our work in our engineering design notebooks kept my students and I very organized and helped us ensure that we followed each step of the engineering design process. Before doing this project, I do not think that I fully understood how important it is to clearly set requirements and constraints as a first step to the engineering design process. Doing this helped to guide the planning process, especially during our brainstorm sessions. Knowing exactly what was expected of them and available to them allowed my students to successfully brainstorm a number of usable ideas and create realistic and followable design plans. I also set time limits on the brainstorm and design sessions. This helped keep my students on task and focused on their projects.

b. Although the engineering design challenge went well overall, there were a few stages where my students and I encountered some trouble. Although building our water heaters seemed simple in theory, we experienced some issues using the materials listed in the *On the Moon Educators Guide*. I found that the tubing was very difficult to bend without forming kinks. I had planned to cover my cardboard with zigzags of tubing but I was unable to exactly follow my plan because of this. My students experienced similar problems. Additionally, the duct tape was not

sticky enough to hold the tubing to the cardboard. By the time I had attached the end of my tubing, the first portion of the tubing was completely unattached. I ended up stapling the duct tape to the cardboard to hold the tubing down. One group of students hot glued the tubing to the cardboard backing. After testing our water heaters, we made some changes to our plans and tried to revise our models. This became very difficult because of our earlier issues with the tubing. This led some of my students to become very frustrated.

c. The following learning standards are associated with this project:

- a. NGSS Science and Engineering Practices: asking questions and defining problems, developing and using models, analyzing and interpreting data, and constructing explanations and designing solutions.
- b. NGSS Disciplinary Core Ideas:
  - i. PS3.A: Definitions of Energy
  - ii. PS3.B: Conservation of Energy and Energy Transfer
  - iii. PS3.D: Energy in Chemical Processes
  - iv. ESS3.A: Natural Resources
  - v. ESS1.B: Developing Possible Solutions
- c. ITEA Content Standards:
  - i. Standard 8: Students will develop an understanding of the attributes of design.
  - ii. Standard 9: Students will develop an understanding of engineering design.
  - iii. Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.
  - iv. Standard 11: Students will develop abilities to apply the design process.
  - v. Standard 12: Students will develop abilities to use and maintain technological products and systems.
  - vi. Standard 13: Students will develop abilities to assess the impact of

products and systems.

- vii. Standard 16: Students will develop an understanding of and be able to select and use energy and power technologies.

This project covered the concepts of heat, heat absorption, conduction, convection, radiation, conversion of light to heat energy, infrared radiation, and measurement. Students also needed to have an understanding of angles and slope to determine how to position their cardboard and plastic cups.

d. Using the engineering design process allowed me to integrate a number of science, math, and engineering concepts into one project. Most of the projects that my students do almost exclusively incorporate science concepts. Using an integrated STEM approach helps students to learn science, math, and engineering concepts simultaneously. I feel that using the engineering design process really helped to push this project towards being an integrated STEM lesson and away from being a strictly science lesson. The Engineering Design process helped my students have a better understanding of some of the work that real life engineers and scientists do every day. This process helped bring this project to life and made my students feel like there were some real-life stakes behind what they were doing. Following the engineering design process allowed my students to have a better understanding of the applications and implications of the concepts that they have been learning about. This helped to keep them engaged and interested in the science, engineering, and math content.

e. I believe that I choose an appropriate engineering design process for my students. We followed the NASA's BEST Engineering Design Process. This engineering design process has six steps, which seemed to be the perfect amount for my 8<sup>th</sup> graders. Each step contained a manageable amount of things to do and think about. I felt that the NGSS Engineering Design Process was too simplified for my students and did not break down each step enough. I also felt that the Dartmouth Design Process was too complex for my students and included too many steps that were not necessarily relevant to this project or appropriate for my students in the time that we had.

f. If I did this project again with students in the future, I would definitely still use the NASA's BEST Engineering Design Process. I would also allow students to work in larger groups. Because of pandemic restrictions, I was only able to do this project with two groups of two people each. I would prefer for each group to have three or four students. In the future, I would like to provide my students with a template for the engineering design notebook. This type, I let each group type up their notebook however they wanted and then I reformatted everything. I would also make sure that I clearly explained the goal and constraints at the beginning of the project. I don't feel that I explained what materials would be available to students and what some of the other constraints were at the start of this process, which led to some confusion during the brainstorming and design stages. Once I explained everything more clearly, my students were able to successfully brainstorm and create drawings and written descriptions of their designs. In the future, I would also try to find better tubing and a different method of attached the tubing to the cardboard. I would like to make several more prototypes with different types of tubing to see what works best. I also would like to try using hot glue to attach the tubing to the cardboard because duct tape and staples seemed to be ineffective. Although it was not really a factor with my small group of students, I would like to be able to find a quicker way for student groups to share their designs with the class. It was very time consuming to watch each group set up their heater and measure their water temperature.

# My Engineering Design Notebook: Feel the Heat (Water Heater)

## Ask/Identify the Problem:

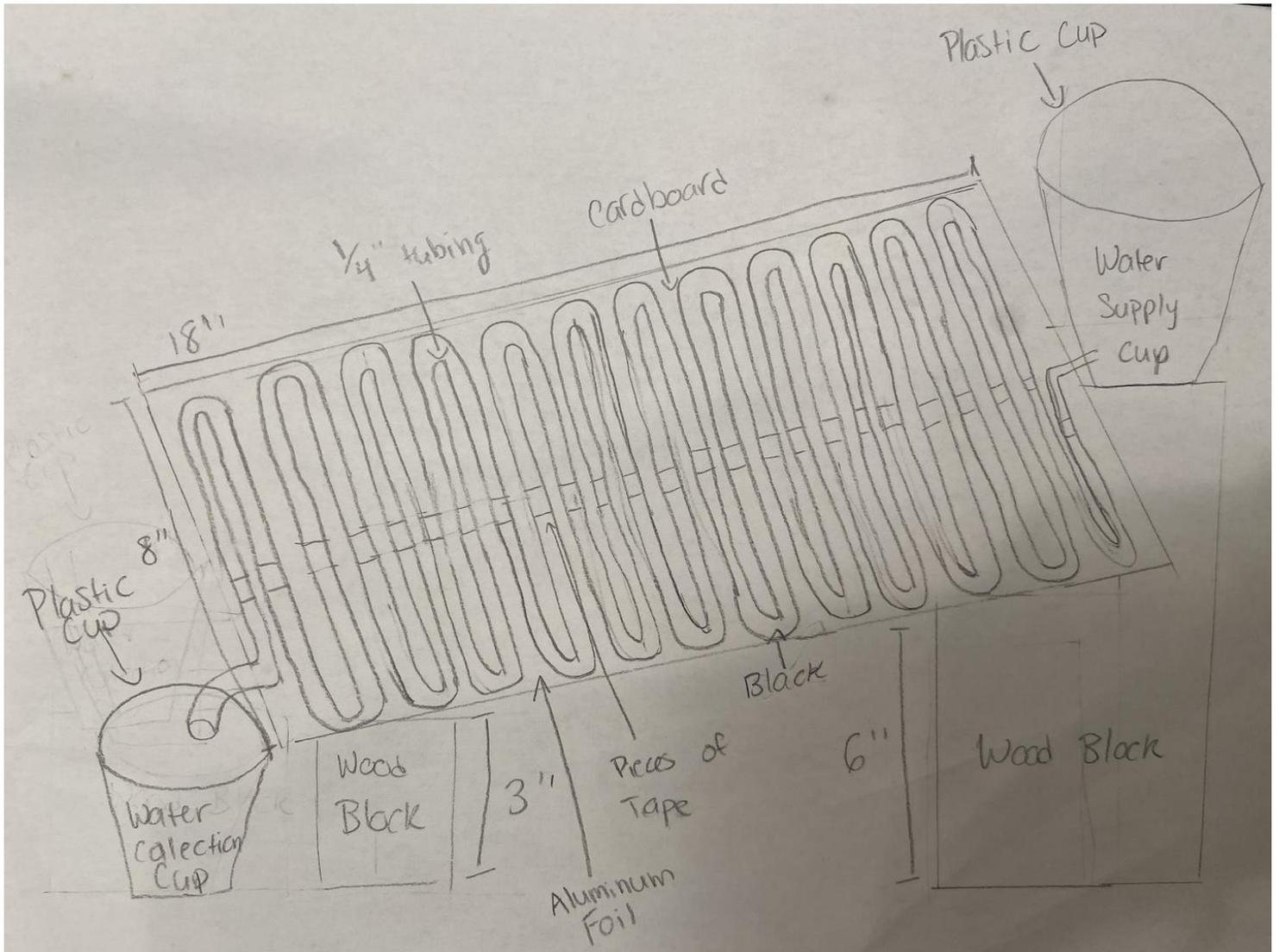
The moon can be twice as cold as Antarctica. Although the moon is very cold, there are still areas on the moon that receive almost constant sunlight. As astronauts begin to spend more time on the moon, they will need to be able to build and heat structures to protect them from the moon's freezing temperatures. There is no gas or electricity on the moon that can be used to heat these buildings. We need to find a way to efficiently heat these buildings without using gas or electricity.

## Imagine/Brainstorm:

- Solar Water Heater
  - Moon receives a lot of sunlight
  - Using tubing to heat water
  - Mount the tubing to a hard surface
    - Cardstock
    - Cardboard
    - Wood
  - Paint the tubing black to absorb as much heat as possible
    - No part of the heater should be light colored
    - The cardboard will be covered in aluminum foil to reflect heat onto tubing
  - Water should move through the tubing very slowly to maximize exposure to the lamp
    - Use a large piece of cardboard
    - Mount the tubing so that it goes back and forth across the cardboard in a zigzag
    - Create as many zigzags as possible so that the water spends more time in the tubing and heats up more
    - Zigzags should be very tight so that the water moves slowly but should also be loose enough that the water does not get stuck in the bends
  - The cardboard backing should be slanted so that water moves from the supply cup to the collection cup
    - This should have a very slight slant so that the water moves as slowly as possible
    - If the water moves slowly, it will stay in the tube longer
    - If the water stays in the tube longer, it will get warmer
    - The cardboard needs to be tilted enough so that the gravity pulls the water through the tubing

### Plan/Design:

I will build my heater using an 18"x8" piece of cardboard and plastic tubing. The cardboard will be covered with aluminum foil to reflect heat onto the tubing. Plastic tubing will be attached to the cardboard using duct tape. The plastic tubing will zigzag back and forth across the 8" side of the cardboard. The tubing will zigzag back and forth repeatedly from one end of the cardboard to the other. The plastic tubing will be painted black to absorb and retain the most heat. One end of the cardboard will be placed on top of a 6" tall wood block. A plastic cup will also be placed on top of the wood block. A hole will be made in the bottom of the cup and the tubing will be placed through the hole. This cup will be the water supply cup. The other side of the cardboard will be placed on top of a 3" wood block. A plastic cup will be placed next to this wood block. The other end of the tubing will feed into this cup. This cup will be the water collection cup. The water supply cup will be filled with water and the water will flow slowly through the tubing to the water collection cup. The temperature of the water will be taken in the water supply cup and the water collection cup.



### **Create/Build:**

I faced some challenges while building my heater. The first challenge was that the tubing was unexpectedly sticky. The next challenge was that the tubing was not as pliable as I had anticipated. This made it difficult to zigzag the tubing as much as I had originally planned to without forming kinks. My prototype has far fewer zigzags than I had planned. Additionally, the duct tape was ineffective in attaching the tubing to the cardboard backing. By the time I had attached the end of the tubing, the other side had already come apart from the backing. I ended up stapling the duct tape to the cardboard backing to hold the tubing in place.



### Test and Evaluate:

I placed one end of the heater on top of a bucket that was 6.75" tall. I placed the other end of the heater on top of a mug that was 3.75" tall. I made a small hole in the side of a plastic cup and inserted the end of the tubing into the hole. The plastic cup was placed on top of the bucket. A measuring cup was then placed next to the mug. The other end of the tubing was placed into the measuring cup. I took the temperature of the water before adding it into the plastic cup, which acted as the water supply cup. I then filled the cup with water. A lamp was held above the heater as the water moved through it. The water was collected in the measuring cup, which acted as the water collection cup. Once the cup had collected  $\frac{1}{4}$  of a cup of water, I took the temperature of the water in the cup. This procedure was repeated two more times.



Trial Number	Temperature of Water in the Supply Cup	Temperature of Water in the Collection Cup	Change in Temperature
1	15.2°C	26.2°C	11.0°C
2	15.2°C	26.3°C	11.1°C
3	15.2°C	26.1°C	10.9°C
Average:	15.2°C	26.2°C	11.0°C

The average change in temperature of the water from the supply cup to the collection cup was 11.0°C. I did not expect the change in temperature to be this high. Overall, I think that the design of this heater was effective. The water moved slowly through the heater and increased in temperature. Painting the tubing back and covering the cardboard in aluminum foil seemed to help increase the temperature of the water. I would like to redesign my heater so that the water moves more slowly through it and has more time to heat up. Since the tubing cannot bend anymore, I will decrease the angle at which the heater is placed.

### **Improve/Redesign:**

Since I could not remove the tubing or bend it anymore without forming kinks in the tubing, I decided to only change the angle at which the heater was held. Instead of having one end placed higher than the other, I laid the heater flat on top of the 6.75" bucket. When I did this, the water did not move through the heater. I then decided to slightly increase the angle. I placed one end of the heater on top of the 6.75" bucket and placed the other end on top of a 5.5" cup.

Trial Number	Temperature of Water in the Supply Cup	Temperature of Water in the Collection Cup	Change in Temperature
1	15.2°C	27.3°C	12.1°C
2	15.2°C	27.3°C	12.1°C
3	15.2°C	27.2°C	12.0°C
Average:	15.2°C	27.3°C	12.1°C

The redesign/modification of my heater increased the change in temperature of the water from 11.0°C to 12.1°C. Because the height difference between the two cups decreased, the water was able to move more slowly through the heater. This gave the water more time to heat up and in turn increased the change in water temperature.

### **Share the Solution:**

Each group demonstrated how their water heater worked. Each group shared the results of their three trials after completing their original design. Each group also shared the changes they made during the redesign and the results of the testing after the redesign. Students shared what they thought worked well and what they thought did not work well about their projects.

## **Group 1: Engineering Design Notebook: Feel the Heat (Water Heater)**

### **Ask/Identify the Problem:**

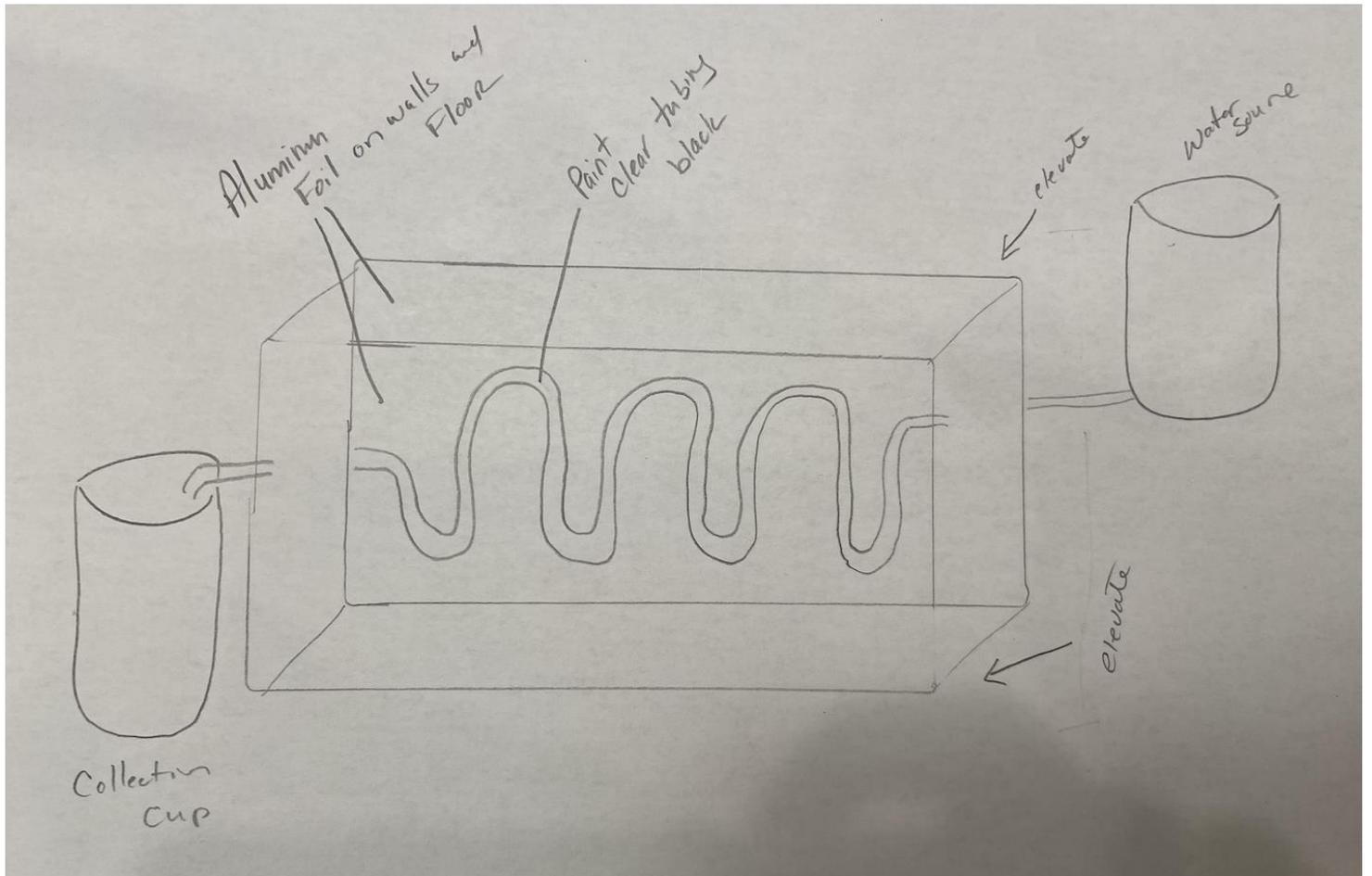
The moon is colder than Antarctica. Astronauts will need to heat buildings to provide warmth from the low temperatures. Due to the lack of electricity, other methods will be needed to provide heat.

### **Imagine/Brainstorm:**

- use available resources such as the sun and water
- place device in direct sunlight
- use a dark tubing to absorb sun quicker
- zig zag tubing to slow down the water flow so that it can heat as it travels in tubing
- use gravity to control water flow
- place heater close to source that requires heating
- recirculate the water
- Reflect as much of the sun as possible onto the tubing

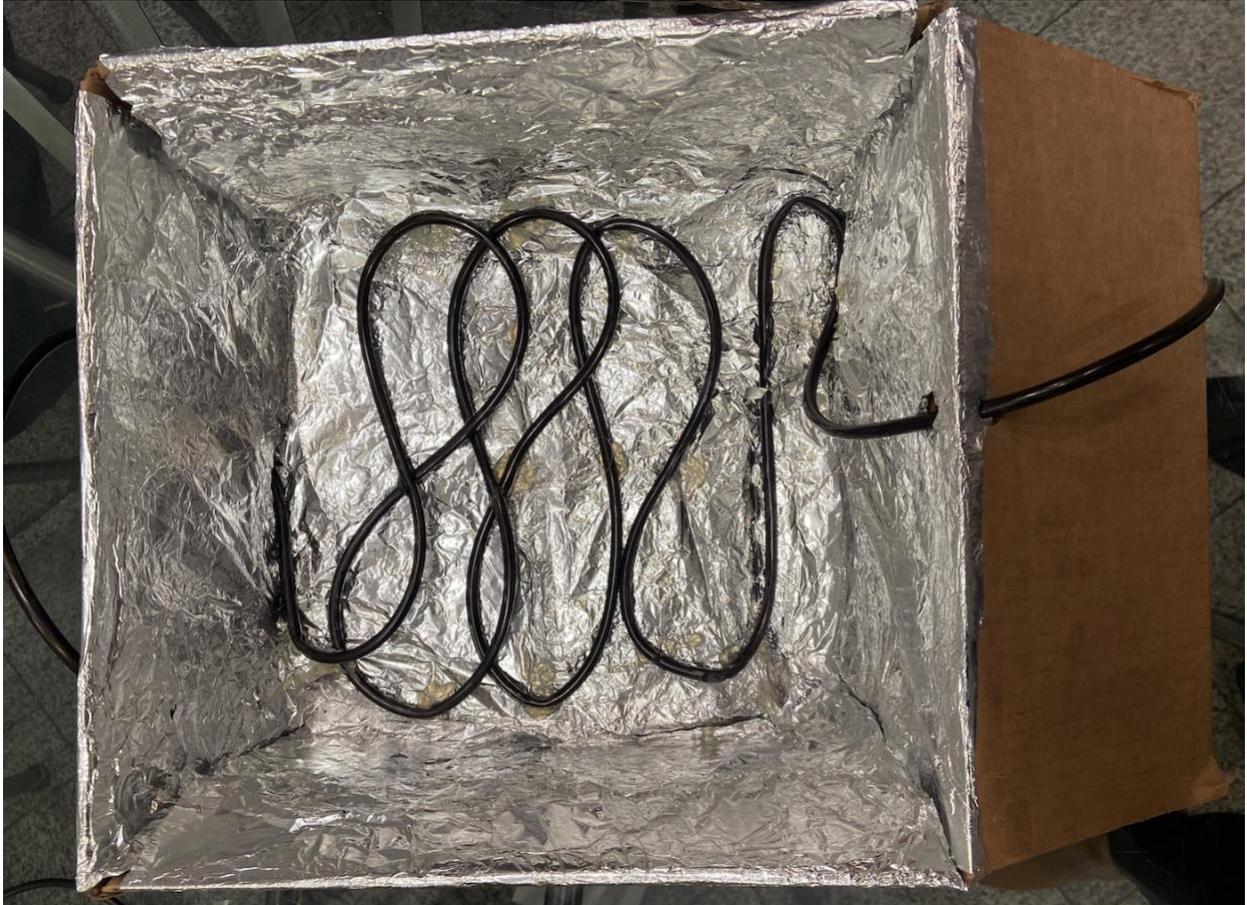
### Plan/Design:

We will line a cardboard box with aluminum foil on all sides and the bottom. We will paint the clear tubing black using a sponge. We will then zigzag the tubing on the bottom of the box and attach it with hot glue. One end of the tubing will be poked through the end of the box and placed through a hole in the bottom of the plastic water supply cup. The other end of the tubing will be poked through the other end of the box and placed in the water collection cup. The box will be elevated so that gravity can carry the water from the supply cup to the collection cup.



**Create/Build:**

We had some challenges while building our heater. The tubing kept kinking so the curves had to be made wider. This made it so that less tubing could be used in the heater. We could not make as many zigzags as we originally planned.



### Test and Evaluate:

The box was placed on a 6.75 in high bucket. A lamp was placed over the box above the tubing. One end of the tubing was placed in a plastic cup above the box and the other end was placed into a measuring cup below the box. A lamp was held above the box over the tubing. Water was poured into the cup to flow through the tubing and emptying up into the measuring cup. The water temperature was taken prior to pouring it into the cup. The water temperature was again taken after it had flowed through the tubing and into the measuring cup at the 0.25 full mark.



Trial Number	Temperature of Water in the Supply Cup	Temperature of Water in the Collection Cup	Change in Temperature
1	15.2°C	22.6°C	7.4°C
2	15.2°C	22.5°C	7.3°C
3	15.2°C	22.7°C	7.5°C
Average:	15.2°C	22.7°C	7.4°C

After three trials, the average temperature change was 7.4°C. The water flowed through the tubing and emptied into the measuring cup too quickly. There was not enough surface area to warm up the water. The aluminum foil in the box design was helpful in containing the heat from the lamp. Although, the tubing was too short to heat up the water sufficiently.

### **Improve/Redesign:**

We wanted to increase the amount of tubing that was inside the box. We bent the sides of the box to create a larger base. Then, we removed the tubing and reglued it. This let us use more tubing than our first prototype. We tested our remodeled prototype the same way that we tested our original design.

Trial Number	Temperature of Water in the Supply Cup	Temperature of Water in the Collection Cup	Change in Temperature
1	15.2°C	23.4°C	8.2°C
2	15.2°C	23.1°C	7.9°C
3	15.2°C	23.3°C	8.1°C
Average:	15.2°C	23.3°C	8.1°C

The redesign/modification of my heater increased the change in temperature of the water from 7.4°C to 8.1°C. This happened because the water took longer to move through the heater and had more time to heat up.

### **Share the Solution:**

We showed the other groups how our heater worked. We also told them our original results and how we changed our design after the first three trials.

## **Group 2: Engineering Design Notebook: Feel the Heat (Water Heater)**

### **Ask/Identify the Problem:**

The moon, especially at its polar regions, is very cold. Astronauts will need to heat the building that will make up a lunar base. Because of the strong sunlight even in the cold regions, scientists theorize that may be possible to use solar energy to heat water that could be used to heat dwellings.

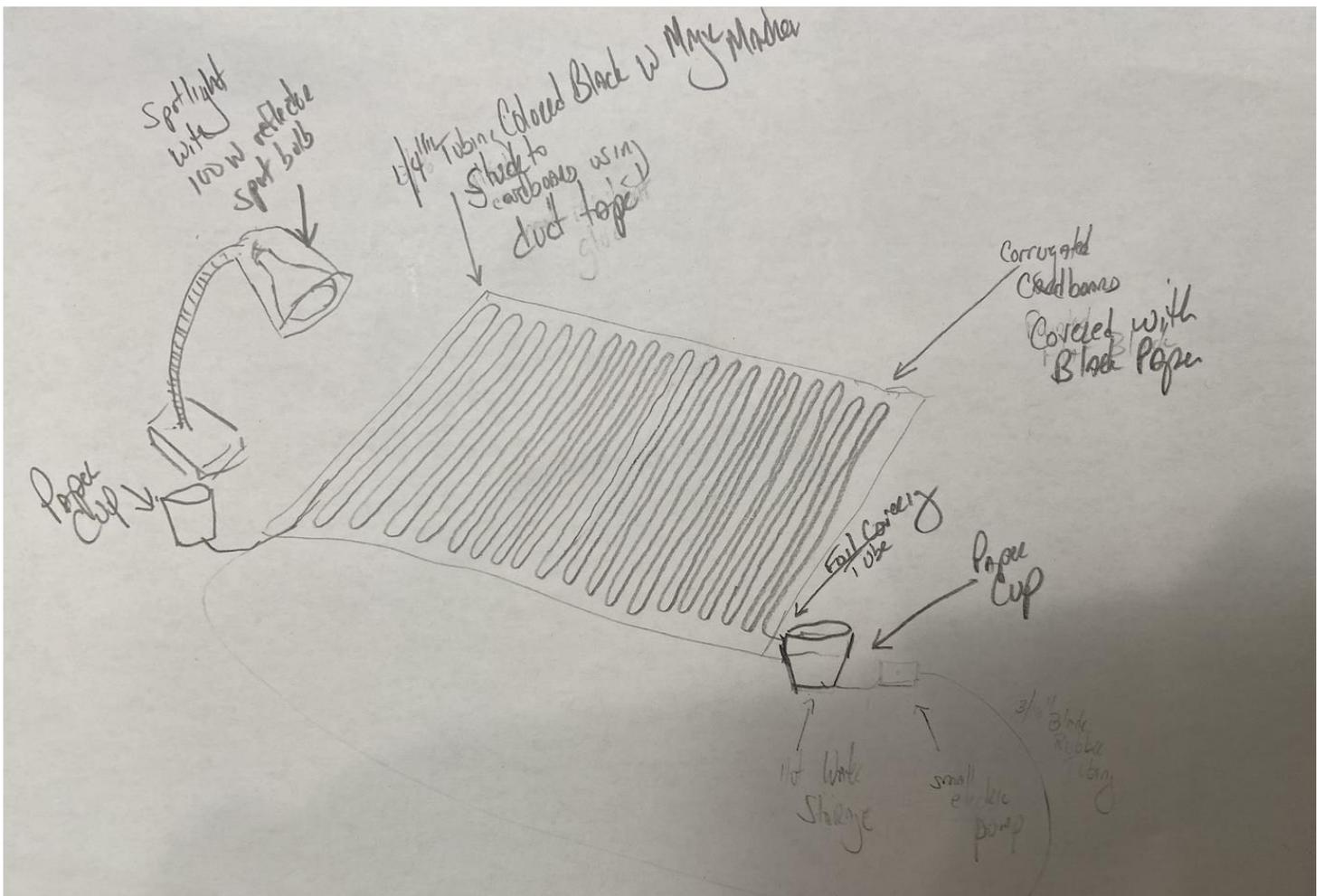
### **Imagine/Brainstorm:**

- Use dark background
- Zigzag tubing tight enough to increase tubing run, but leave room between rows
- Have water move at a slow steady pace through the tubing to increase time exposed to the sunlight
- Use dark tubing
- Use thin tubing
- Maybe use a liquid other than water that holds more heat

## Plan/Design:

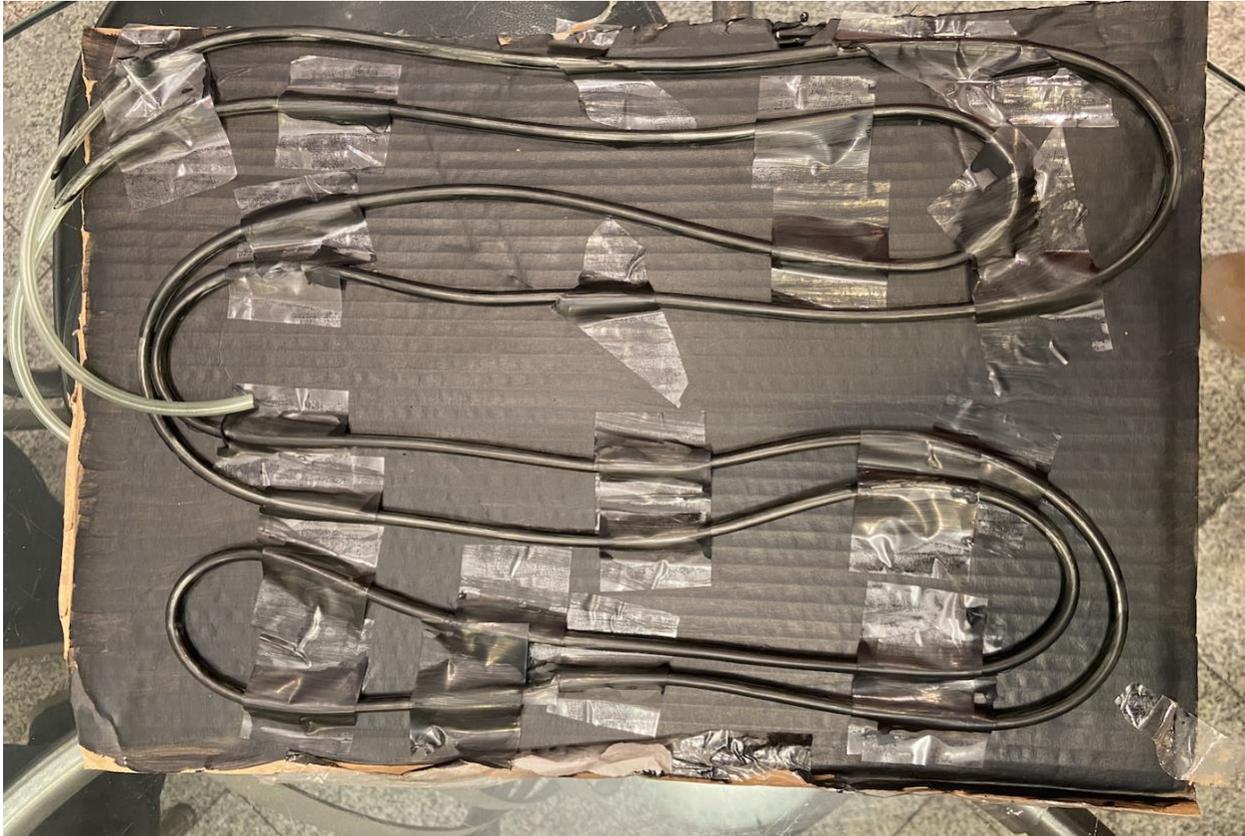
We will cover an 11x17 sheet of cardboard with black paper. We will then color  $\frac{1}{4}$ " clear plastic tubing with black marker and affix it to cardboard using duct tape. We will attach the tubing in a zig-zag pattern across the paper, securing with tape at each change in direction.

Approximately 6" of tubing will hang off the cardboard on either side. We will poke a straw through the bottom of a paper cup and seal the hole surrounding the straw with duct tape. The straw will be attached to the tubing on one side of the cardboard. This cup will be positioned slightly higher than the cardboard backing. We will position another cup under the other end of the tubing.



**Create/Build:**

We painted the cardboard black using black acrylic paint. We then attached the tubing to the cardboard with tape in a zigzag pattern. Some of the duct tape did not stick to the cardboard so we had to staple it down. The tubing was painted black using the same paint. Finally, a cup was attached to the beginning of the tubing. We decided to put both ends of the tubing on the same side of the cardboard.

**Test and Evaluate:**

The prototype was tested by filling the cup with room temperature water. The temperature was recorded before the water flowed through the project. A halogen lamp was placed approximately 8" above the project as water flowed through the tubing. When  $\frac{1}{4}$  cup of water had passed through the project and had been collected in a measuring cup the temperature was recorded again. The difference between the starting and ending temperatures was calculated.



Trial Number	Temperature of Water in the Supply Cup	Temperature of Water in the Collection Cup	Change in Temperature
1	15.2°C	22.5°C	7.3°C
2	15.2°C	22.9°C	7.7°C
3	15.2°C	22.7°C	7.5°C
Average:	15.2°C	22.7°C	7.5°C

The average change in temperature of the water after passing through our prototype was 7.5°C. The temperature change that we measured was more than we anticipated. Overall this design was promising as a way of heating water on the moon. We believe that our prototype could be improved by using a curved, dish shaped item for the backing instead of a piece of cardboard. This might concentrate the heat given off by the lamp.

**Improve/Redesign:**

We decided to try to improve our project by insulating the tubing. We placed cotton balls all around the tubing. We also tried tilting our prototype instead of leaving it flat on the table.

Trial Number	Temperature of Water in the Supply Cup	Temperature of Water in the Collection Cup	Change in Temperature
1	15.2°C	22.9°C	7.7°C
2	15.2°C	23.1°C	7.9°C
3	15.2°C	22.9°C	7.7°C
Average:	15.2°C	23.0°C	7.8°C

The redesign/modification of my heater increased the change in temperature of the water from 7.5°C to 7.8°C. Insulating the tubing did not seem to help increase the temperature that much. Tilting our prototype also did not seem to increase the temperature much because both ends of the tubing were on the same side of the cardboard.

**Share the Solution:**

We showed the other groups how our heater worked and we told them what we liked and did not like about our original design. We also told them our original results and how we changed our design after the first trials.