THE FINAL DESIGN REPORT
FOR A STEM EDUCATIONAL PROJECT
IN SANTA RITA, COLOMBIA


By:
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A final design report
submitted in partial fulfillment of the requirements for

EDNS 492: Senior Design II


Department of Engineering, Design, and Society
Colorado School of Mines
Golden, CO


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# Appendices

*Appendix A: Module 1 Materials*

## M1A: Lesson Plan Teacher's Document

### Lesson Plan

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**Learning Objectives**

- Understand how filtration works.
- Design a water filter.
- Apply problem-solving skills and critical thinking.
- Learn how to work in teams to solve a challenge.

**Lesson Materials**

Below is a list of all the available materials the students may use to construct their water filters. They are not required to use any materials in particular, but they will need a container to hold the water filter components.

- Coffee filters
- Rocks, Sand, Gravel (other natural material)
- Cloth/bandana/paper towels??
- Cotton balls,
- Containers to hold the water filter-plastic bottles, cups
- Sealing material- tape, glue
- String
- 1/2 gallon of dirty water
- 1 Clear container

Also take into account the handouts: Background info sheet and Instructions sheet

*Filtrate Instructions*

To make the water the students will filter, please take ½ gallon of tap water and mix into the water some combination of suspended solids and/or larger. The specific makeup of the water can include anything available at your discretion, but it must be made of something the size of suspended solids or larger (so it can be filtered). Some sources of ingredients to possibly consider would be stream banks (can collect leaves and sticks), the trash (small wrappers), and maybe even food (consider fruit remains, crumbs, etc). Basically, anything that regularly ends up in stream water is a good ingredient to use for the dirty water.

**Lesson Procedure**

*How will you introduce the topic?*

Engineers solve problems of all sizes. From spaceships to nanobots, engineers apply the same general STEM design process to create solutions. In this program, students will explore the engineering design process through the topic of water quality and filtration. The young engineers will have the opportunity to apply their newly attained knowledge by designing their own water filtration prototype. Students are encouraged to compete with one another to emulate a real engineering design competition. The field of STEM needs creative minds like yours to help communities by designing real-world solutions like this one.

The following link provides an inspirational video that could be used:
https://www.youtube.com/watch?time_continue=1&v=zgB-Diy8imo&feature=emb_titl

*What's the best way to teach this information to your students?*
A hands on approach is the idea behind this module. While other modules will focus more on lecturing, this module is designed to take a kinesthetic strategy to helping the students understand water filtration. There is a lot of freedom within this module as far as how the students will work; they may create individually or in groups. The teacher is best suited to make that call based on the character of the classroom. While the students are building the water filters, there will also be a lot of room for variation. Teachers may time the students or they may give them as much time as each student feels appropriate. Teachers have the freedom in how they will deliver the information, but the main takeaway is that the students will have a water filter prototype with a competition at the end. It is also highly suggested that teachers allow students time for the reflection questions at the end to make sure they evaluate what they've learned. It could possibly be turned into a classroom

*How can you incorporate problem solving and critical thinking?*
The students will be provided the opportunity to problem solve when they construct their water filters. However, an approach is needed to get the students critically thinking about their activities. At the completion of the competition, students will reflect on their experience through the reflection questions. It may be helpful to get students critically thinking prior to the activity as well. One potential option could be a class discussion: the teacher facilitates a conversation about water filtration following the presentation of the background information. The background information can be read individually and then the teacher can follow up by allowing students to ask questions and/or recap what they understood from the background information.

*What real-life scenarios relate to this topic?*
Some ways to relate water filtration to real life could be cleaning a pool. A poolman walks around a pool with a strainer type tool where he can pull trash and contamination out of the water. Have the students consider why he might use a tool like that, what the benefits of the features of the tool are, and what its function is.

*Would the module best be performed with group work?*
This is completely up to the teacher's discretion. Consider how your class typically works. This module can be performed alone or in groups. Some possible things to consider may be the availability of materials and that it may be cheaper to supply water filters if the students work in groups.

**Key Module Steps:**

1. Explore: Students discover a concept
2. Learn & Practice: Students apply their discoveries

3. Reflect: Students review what they've learned
4. Reinforce: Students apply their knowledge to problem-solving scenarios

**Assessment Method**

Examples: Quizzes, Hands-on activities,Writing assignments, Group presentations, Exit slips, Class journal entries, **kahoot quiz**

*Kahoot Quiz*

1. What is the point of water filtration?
    a. To make water colder
    b. To boil water
    c. To make water blue
    d. To clean water

2. What kitchen item is water filtration similar to?
    a. A colander/strainer
    b. A can opener
    c. A cutting board
    d. A mixer

3. How long can we go without water?
    a. A month
    b. A week
    c. Three days
    d. A few hours

4. What are some common layers of a water filter?
    a. Chlorine
    b. Sand
    c. Plastic bags
    d. Leaves

5. What type of contamination does the top filter layer catch?
    a. Black contamination
    b. Plastic contamination
    c. Larger contamination
    d. Liquid contamination

Link to finalized quiz: https://create.kahoot.it/details/608d2c34-d137-43ac-9669-a6f1066c3012

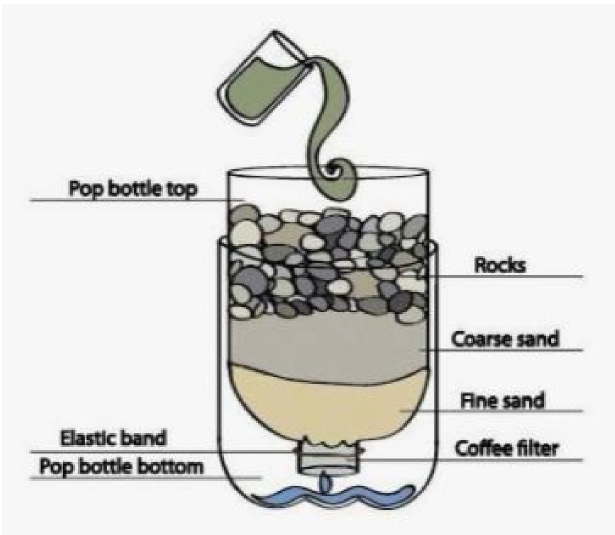
**Lesson Reflection**

The lesson reflection portion of a lesson plan encourages teachers to take notes on how to improve a lesson after it has been completed.

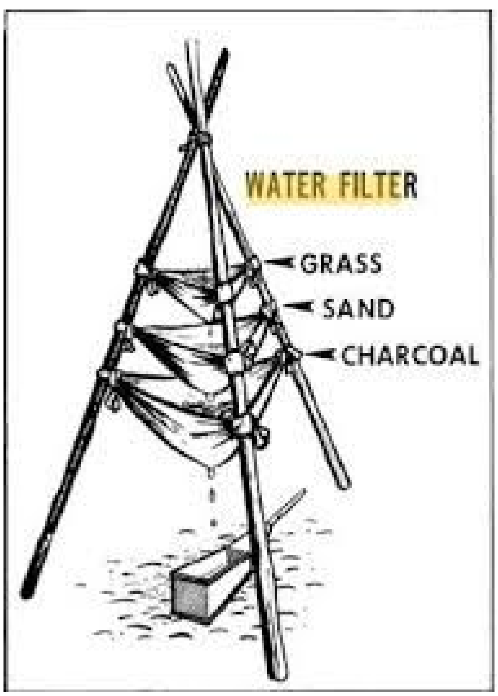
1. Did any part of the lesson take longer than expected?
2. Was there a portion that students asked for a lot of help with?

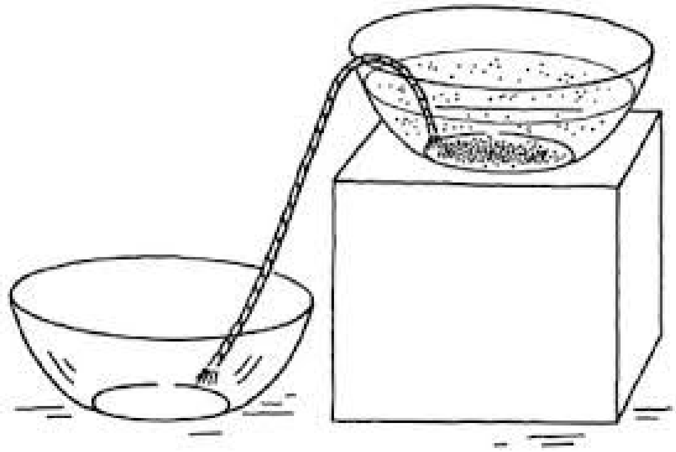
3. Did students breeze through the information with no problem?
4. Were students engaged and interested in the lesson?
5. Were the objectives met by most (or all) of the students?

**Water Filter Examples**





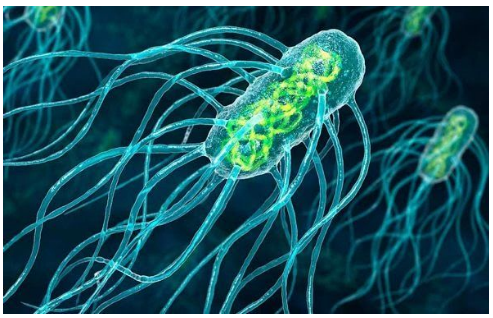


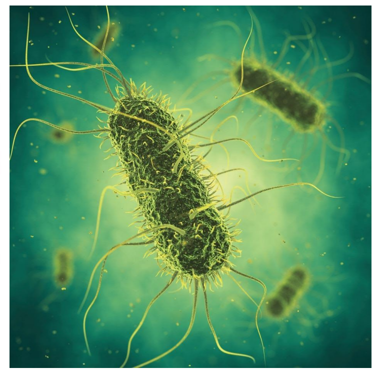



## M1B: Understanding a Water Filter Handout

# Understanding a Water Filter

**Why do we need water?**
Water is important for every living thing on this planet. You can go about 3 days without water. Without water, our bodies cannot work properly. When we aren't drinking water, we risk our health, our strength, or energy, and potentially our life. We don't want dirt in our water because it tastes yucky and It doesn't look good to drink. Dirty water can make people sick because it can contain bacteria, which are tiny cells that make people sick.

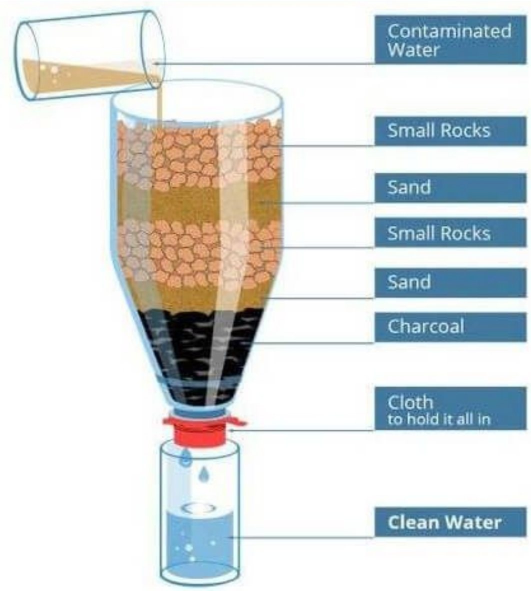




**What is a Water Filter?**
When you drink a glass of water what does it look like? Is it clear or cloudy? It is usually clear because we use a water filter! Water filters help to clean all of the dirt out of the water before we drink it. Using different kinds of materials, we can remove things out of the water. After a certain amount of time, filters can get clogged. This is because they have removed too many things from the water, so water won't flow through the filter as quickly. Filters have to be cleaned when this happens or they won't remove things from the water as well.

**How does it work?**

Water filters work by letting water in but keeping the gunk out, similar to a strainer like this! The water can pass through the small holes, but the big things we don't want in our water get left behind. Big things, such as rocks and leaves, can end up in our water as the water flows through a stream. There are also smaller things that we can not see, such as bacteria and other bad things that can make us sick or make or water taste gross. These small things will pass through the small holes of a water filter with the water, so there are other ways water must get cleaned even after getting filtered! But, water filtration definitely plays a big role in cleaning a whole lot of gunk from our water!




**What goes into a water filter?**

Water filters have several layers. The upper layers are meant to catch larger items in the water while the lower layers are meant to catch the smaller items. Water is poured through the top of the filter and it flows through the various layers inside. It is important to consider what makes up each layer, how deep each layer is, and the order the layers are placed. We will explore how these important features of a water filter work together to clean our water!

# M1C: JASON Learning Design Matrix Document

## General Instructions for Using the Decision Matrix

### Constraints and Considerations

Many complex decisions have certain constraints and considerations that must be considered when making a choice. A constraint is a limitation or restriction. A possible choice that does not meet the constraint will not work. On the other hand, considerations are factors that you want to consider in making a decision, but are not "deal-breakers." For example, imagine you are buying a car. There are five people and a large dog in your family. Your car must have room for five people and a dog. If it does not, the car will not work for your family. This is a constraint. You would also like to get a car with good gas mileage, and you would prefer one that is blue. These factors are considerations, because a red car or one with only average gas mileage would still work for your family. You would just give more weight to a car that was blue and had good gas mileage if such a car were among your choices and had room for five people and a dog.

### Using the Decision Matrix

1. List each criterion (or factor) you need to consider when deciding on best overall solution or design.
2. Assign a weight for each criterion from 1 to 5, (with 5 as the highest value). This should reflect how important you think the criterion is. Thinking about whether it is a constraint vs a consideration may also help you determine its weight (a constraint should be weighted more heavily). This is a judgement call students should make. It is important for students to understand that they are not ranking these factors in order of importance. Multiple factors may have the same importance.
3. For each criterion, score each option on a scale of 1-5 (5 being best) based on how well that option seems to meet the criteria.
4. Multiply the weight for each category by the score you gave each option to get the weighted score. Calculate total weighted scores for each option and compare.
5. Students should critically think about whether or not the outcome makes sense overall. If it doesn't, it may mean students need to go back and review how they assigned values or weighted certain categories. Alternatively, it may mean that the matrix is revealing an outcome they hadn't fully anticipated, and thus should consider that option more seriously. The more often students practice using matrices, the more meaningful and reliable this tool becomes.

### Sample

| What Should I Have for Lunch? | | | Options | | | |
|---|---|---|---|---|---|---|
| | | | Hamburger | Salad | Option C | Option D |
| Selection Criteria/Category | Weight (1-5) | Multiply | Score / Weighted Score | Score / Weighted Score | Score / Weighted Score | Score / Weighted Score |
| Taste (Should taste good) | 5 | x | 5 / =25 | 2 / =10 | | |
| Nutrition (Should be healthy) | 2 | x | 2 / =4 | 5 / =10 | | |
| Cost (Less expensive scores higher) | 3 | x | 3 / =9 | 3 / =9 | | |
| | TOTAL SCORE | = | 38 | 29 | | |

https://www.jason.org/wp-content/uploads/2016/05/JASON-Learning-Decision-Matrix-Engineering.pdf

# M1D: Water Filter Construction Handout

## Water Filters

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**Learning Objectives**

- Understand how filtration works.
- Design a water filter.
- Apply problem-solving skills and critical thinking.
- Learn how to work in teams to solve a challenge.

**Material Lists**

- Coffee filters
- Rocks, Sand, Gravel (other natural material)
- Cloth/bandana/paper towels??
- Cotton balls,
- Containers to hold the water filter-plastic bottles, cups
- Sealing material- tape, glue
- String
- 1/2 gallon of dirty water
- 1 Clear container

**Instructions**

1. Gather materials
    a. Choose any portion of available materials you believe will successfully filter your water. All students will need to grab a container and a type of sealing material, but the parts that will go inside the water filter are up to you!
2. Build your water filter
    a. Make your water filter! Keep in mind you need to collect the clean water in the clear container. Take into consideration what types of impurities still went through your water filter, what materials soak up water and which don't.
    b. Think about the layout of your water filter. Are you placing the filtering materials in the best order? Should you rearrange materials?
    c. Also, consider how much water you will be able to filter. Maybe your water filter will get easily clogged after a cup of water. Consider ways to filter the most water effectively.
3. Test your water filter
    a. Place your water filter into the containment tub. (In case of spills) Take the X gallons of water and put it into your water filter. Filter small portions (maybe one styrofoam cups worth) at a time so as not to overwhelm the water filters or cause them to tip. Wait until all of the water filters through.
4. Compare
    a. How clean is your water? Maybe have a line of dirty to clean?
    b. Who had the cleanest water? Look into the clear containers that collected all of the filtered water. Judge the clearest water by seeing which water is the least discolored.

c. Who had the most water?
d. Who had the most creative design?

**Reflection**

1. What is the right balance of materials for your water filter? Too many materials may cause you to filter too little water because the filter gets easily clogged. Not enough materials and you will get too many impurities passing through. What do you need to know about the water to strike this balance? What background information may be helpful when designing a water filter? What other materials might be great at filtering water?
2. Think about the assembly of your water filter. Did the materials stay together while you filtered the water, or were you struggling to keep the water filter intact? Did any leaking take place? How well sealed was your water filter? What materials helped/would help with sealing?
3. Would you feel comfortable drinking the filtered water? If not, what would you still be worried about? How might you eliminate this worry?

## Engineering Analysis

Before creating the water filters with the different classes during the testing phase, each member of the team created their own water filter to evaluate the effectiveness of their designs. The properties the team evaluated were the removal efficiency of the water filter, the turbidity, and the flow rate. There were five water filter designs total, each with a different combination of coffee filters, sand, cheesecloth, woodchips, and cotton balls. Table 3 below represents the different combination of materials for each water filter. The advisor for the engineering calculations, Dr. Christopher Bellona, also mentioned the importance of the permeability coefficient for filter efficiency.

Table 3: Water Filter Combinations

| Trial # | Water Filter Combination of Materials |
| --- | --- |
| **1** | Two coffee filters, sand at the bottom, two layers of cheesecloth, woodchips, handful (10-15) of cotton balls |
| **2** | Two layers of cheesecloth, two coffee filters, handful of cotton balls |
| **3** | Handful of cotton balls, three coffee filters, sand, woodchips |
| **4** | Small amount (5-10) of cotton balls, two coffee filters, sand, woodchips |
| **5** | Several (>15) cotton balls, two coffee filters, one layer of cheesecloth |

### *Removal Efficiency*

The removal efficiency was measured by calculating the difference between contaminant concentration of the initial water created and the contaminant concentration of the filtrate and then dividing that value by the concentration of the initial water. The procedure for measuring total suspended solids was applied for the water concentration using a 1.2 micron sized filter. Overall, the filters generally had very high removal efficiencies, all over 90%. One water filter represented water that was doubly filtered (the filtrate of Trial #1), and it's removal efficiency was lower during the second pass. Table 4 below represents the calculated removal efficiencies with Trial #2 representing the doubly filtered water.

Table 4: Removal Efficiencies

| Trial # | Removal Efficiency | | Unit |
| --- | --- | --- | --- |
| | mass of contaminants | 0.189 | grams |
| | volume of influent | 0.072 | Liters |
| | | | |
| **1** | initial water concentration | 2.63 | g/L |
| | mass of filtered contaminants | 0.010 | g |
| | final water concentration | 0.139 | g/L |

| | | | |
|---|---|---|---|
| | percent removed | 94.71% | |
| | | | |
| **2** | initial water concentration | 0.139 | g/L |
| | mass of filtered contaminants | 0.004 | g |
| | final water concentration | 0.05 | g/L |
| | percent removed | 63.54% | |
| | | | |
| **3** | initial water concentration | 2.63 | g/L |
| | mass of filtered contaminants | 0.004 | g |
| | final water concentration | 0.16 | g/L |
| | percent removed | 93.90% | |
| | | | |
| **4** | initial water concentration | 2.63 | g/L |
| | mass of filtered contaminants | 0.004 | g |
| | final water concentration | 0.04 | g/L |
| | percent removed | 98.48% | |
| | | | |
| **5** | initial water concentration | 2.63 | g/L |
| | mass of filtered contaminants | 0.011 | g |
| | final water concentration | 0.08 | g/L |
| | percent removed | 96.78% | |

### *Turbidity*

Turbidity was measured in the lab with a turbidimeter for the five filtrates and the initial water (influent). Turbidity measures the degree to which water loses its transparency due to suspended particulates. The results are indicated below in Table 5. The drinking water standard for turbidity is 5 NTU.

Table 5: Turbidity Measurements

| Trial # | Turbidity Measurements | Unit |
|---|---|---|
| 1 | 204 | NTU |
| 2 | 33.35 | NTU |
| 3 | 97.75 | NTU |
| 4 | 87.7 | NTU |
| 5 | 189.5 | NTU |
| Influent | 756 | NTU |

The turbidity measurements were compared against the concentrations to develop a relationship. The graph of this relationship is reflected below in Figure 7. Generally, lower turbidity reflected a lower concentration. The turbidity of the filtrate ranged from around 75-200 NTU, with the influent turbidity at roughly 800 NTU. Though turbidity decreased significantly with filtration through all of the water filters, it did not bring the water close to the drinking water standard. When the water was doubly filtered, as in Trial 2 (filtrate of Trial 1), the turbidity did decrease by nearly 80%.

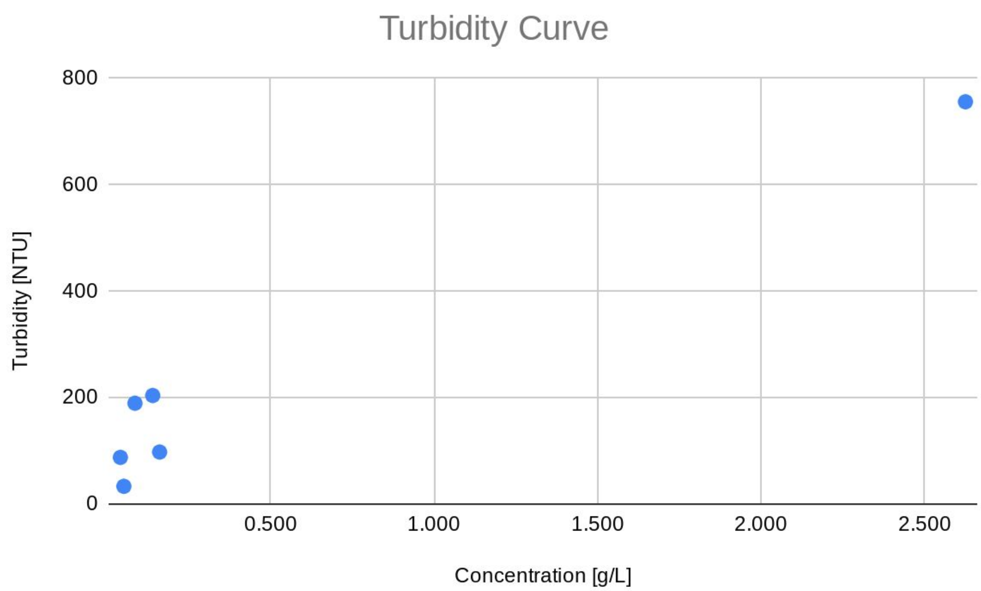



Figure 7: Turbidity Curve for Team Water Filters

In Figure 8 below, the filtrates are grouped in order of decreasing turbidity. Trials 1 and 5 are on the left with Trials 3 and 4 in the middle and Trial 2 on the right. When the filtrates were analyzed, Trials 3 and 4 had the most resting sediment on the bottom of the test tube while Trials 1 and 5 had a more cloudy appearance. This was interesting because Trial 3 had a higher filtrate concentration than Trial 1. However, a likely conclusion could be that Trial 1 had smaller suspended solids that passed through the filter, increasing its turbidity, but not as many large suspended solids which would explain why the contaminant concentration was lower.

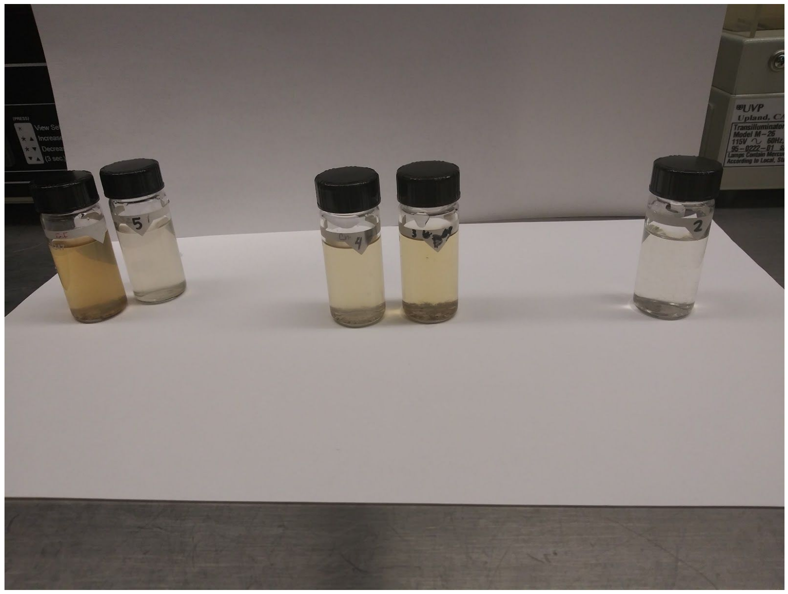


Figure 8: Filtrate Test Tubes

### *Flow Rate*

The final parameter for testing the effectiveness of the water filters was measuring the flow rate. Different amounts of the influent were measured to pour through each filter, which is indicated by the “volume of water passed through the filter”. A timer was started for each trial, sometimes running until all of the water passed through the filter and sometimes stopped prematurely because of a slow flow rate. In instances where the timer was stopped prematurely, the volume of water passing through the filter was adjusted to match the difference between the initial volume and the volume of the influent left. Table 6 below indicates the flow rate results for the five water filters. For Trials #1-4, the flow rate was very similar but Trial #5 had a very slow flow rate. This was attributed to the thick layer of cotton balls that the water filter contained, while the other four did not have as many cotton balls. In future instances of testing the water filters, scenarios like this express how the permeability coefficient could be useful. The permeability coefficient measures the rate at which a molecule can pass a membrane, or in the case of the water filters, the rate at which the fluid will pass the filter layers. However, the depth of the filter media was not measured in these trials. Therefore, the permeability coefficient was not calculated.

Table 6: Water Filter Flow Rates

| **Trials** | **Flow Rate through Filter** | | **Unit** |
|---|---|---|---|
| **1** | volume of water passed through filter | 0.24 | L |
| | time it took water to pass through filter | 14.85 | min |
| | flow rate through filter | 0.016 | L/min |
| | | | |

| | | | |
|---|---|---|---|
| **2** | volume of water passed through filter | 0.24 | L |
| | time it took water to pass through filter | 1.7 | min |
| | flow rate through filter | 0.141 | L/min |
| | | | |
| **3** | volume of water passed through filter | 0.24 | L |
| | time it took water to pass through filter | 1.783 | min |
| | flow rate through filter | 0.135 | L/min |
| | | | |
| **4** | volume of water passed through filter | 0.12 | L |
| | time it took water to pass through filter | 0.93 | min |
| | flow rate through filter | 0.129 | L/min |
| | | | |
| **5** | volume of water passed through filter | 0.07 | L |
| | time it took water to pass through filter | 14.5 | min |
| | flow rate through filter | 0.005 | L/min |

Overall, Dr. Bellona thought Trial #4 was the best water filter. It had the highest removal efficiency, lowest turbidity, and a relatively quick flow rate when compared to the other water filters. By performing this testing phase to measure different filtration qualities, the team felt better prepared when advising students in the classrooms about different successful filter combinations. This would help students avoid designs that would not remove many contaminants or would have too slow of a flow rate.

## Design Solution: Module 1

The final solution of the CARE Team's project took the form of an educational module. This module will be available to the teachers of Santa Rita for application in their own classrooms. After considering all criteria from the engineering analysis and consulting various teachers in the local community, Module 1 was created.

Teaching Module 1 is a five-day module at its core, but it is largely adaptable and moldable in the hands of the teacher. The program can easily be shortened into a single day activity or drawn out into a multi-week experience. The program is centered around the goal of giving students an awareness and rudimentary knowledge of water filtration within engineering. Figure 9 below is the Module 1 Example Lesson Plan to be delivered to the teachers of Santa Rita for their own use and adaptation.

| **Grade Level:** 3-8 | **Teacher/Room:** TBD | **Course:** Engineering/Science | **Date:** TBD | |
|---|---|---|---|---|
| **Unit Vocabulary:** Design, Engineering, Filtration, Debris, Particles, Particulate, STEM (Science, Technology, Engineering, Mathematics), Iteration, resource, society, community, Criteria, Matrix, Approach, Stakeholder, Client, Prototype, Solution, | | | | |
| **Instructional Strategies Used:** lecture, small group and large group discussions, Kahoot, Quizlet flash cards (TBD), BYOD, think-pair-share, individualized practice, graphic organizers, | | | | |
| **Day 1** | **Day 2** | **Day 3** | **Day 4** | **Day 5** |
| **Essential Question:**<br>Who are engineers and what do they do? | **Essential Question:**<br>What is water quality and filtration? | **Essential Question:**<br>How is water quality and engineering related? | **Essential Question:**<br>How is water quality and engineering related? (Part 2) | **Essential Question:**<br>How do engineers compete with other engineers? |
| **Mini Lesson: [30-60min]**<br>• STEM meaning and application<br>**Activating Strategies:**<br>• Initial Kahoot (Things designed by engineers)<br>• STEM Video<br>**Lesson:**<br>• Notes on STEM and its importance [10-20min]<br>• Short Design Activity [20-30min]<br>Engineering Notebook [10min]<br>**Resource/Materials:**<br>• Notes provided by CARE, video, Kahoot quiz | **Mini Lesson: [30-60min]**<br>• Exploring water quality<br>**Activating Strategies:**<br>• Creating the design Matrix<br>• Quizlet cards for the unit vocabulary terms.<br>**Lesson:**<br>• Introduction to water quality and filtration [20-30min]<br>• Water Filtration Example [10-20min]<br>• Engineering Notebook [10min]<br>**Resource/Materials:**<br>• Notes Provided by CARE, Kahoot Quiz | **Mini Lesson: [40-60min]**<br>• Engineering Design Process<br>**Activating Strategies:**<br>• Creative Design Process<br>• Vocabulary Review on Filtration<br>**Lesson:**<br>• Defining your problem and solution criteria [30-40min]<br>• Work on choice of Q and A's [10-20min]<br>• Engineering Notebook [10min]<br>**Resource/Materials:**<br>• Notes Provided by CARE | **Mini Lesson: [50-60min]**<br>• Building your design<br>**Activating Strategies:**<br>• Stakeholder Questions<br>• Vocabulary Review on Filtration and Engineering Process<br>**Lesson:**<br>• Creating Your Prototype [30 mins]<br>• Designing Tests for Prototype [10-20min]<br>• Engineering Notebook [10min]<br>**Resource/Materials:**<br>• Notes Provided by CARE, Design your own water filter supplies | **Mini Lesson: [30-50min]**<br>• Engineering Competition<br>**Activating Strategies:**<br>• Design Competition and testing<br>• Final Kahoot Quiz<br>**Lesson:**<br>• Understanding iterations [10-25min]<br>• Engineering Notebook [10min]<br>• Engineers in competition [10-15min]<br>**Resource/Materials:**<br>• Notes Provided by CARE, video |
| **Differentiation:**<br>***Content/Process/Product:***<br>•<br>***Grouping Strategy (if any):***<br>• ability based on teacher observations and interests. | **Differentiation:**<br>***Content/Process/Product:***<br>• Student Drawn Matrix<br>***Grouping Strategy (if any):***<br>• ability based on teacher observations and interests. | **Differentiation:**<br>***Content/Process/Product:***<br>• Choice Q and A's<br>***Grouping Strategy (if any):***<br>• ability based on teacher observations and interests. | **Differentiation:**<br>***Content/Process/Product:***<br>• student designed solutions<br>***Grouping Strategy (if any):***<br>• ability based on teacher observations and interests. | **Differentiation:**<br>***Content/Process/Product:***<br>• student designed solutions<br>***Grouping Strategy (if any):***<br>• ability based on teacher observations and interests. |
| **Homework:**<br>Review and study notes. | **Homework:**<br>Review and study notes. Sketch your own filter design. | **Homework:**<br>Review and study notes. Re-create your design using the engineering process. | **Homework:**<br>Review and study notes. Work on prototype at home if not finished in class. | **Homework:**<br>Create another iteration of your design to win the next competition. |

Resources and Reflective Notes:

Figure 9: Module 1 General Lesson Plan

Each day follows a general structure. The daily schedule starts with a short lesson and concludes with an activity that utilizes a known and accessible teaching strategy or tool (i.e. turn-and-talks, Q and A, engineering notebook entry, etc). All of the teaching material is delivered to the teacher at least two weeks beforehand. Days 1-3 expose students to the world of STEM and more specifically filtration within STEM. Days 4 and 5 focus on following the engineering design process in the students' creation of their own simple water filter.

Day 1 begins with a Kahoot! quiz or alternative pre-test on the module topic for the teacher to gauge the class level of exposure to the topic. Afterwards, there is a short video inspiring students to explore the areas of STEM. A lesson on STEM and its importance is then given, referencing the video and exposing students to its real-world applications (APPENDIX M1A). Afterwards, the students write an entry in their notebooks and spend some time recording their daily findings and observations.

Day 2 begins with a short reading that explains how simple water filters work and how they can be created (APPENDIX M1B). Afterwards, students are placed in groups and asked to think about why they might want filtration themselves. This exercise gives students the chance to begin thinking about the engineering design process in filtration without formally introducing them to it yet. The day is concluded with students documenting their findings and observations in their engineering notebooks.

The Day 3 Learning objective is to introduce students to the engineering design process. It begins with a short vocabulary review on STEM and filtration terms discussed the two days before. Afterwards, the engineering design matrix is explained using the JASON Learning handout (APPENDIX M1C). Once a basic understanding of the design matrix is understood, students are asked to make a design matrix for their own water filter in their engineering notebooks.

Most of Day 4 is spent on the creation of students' water filters. Given a list of materials, the students have the opportunity to use their newly acquired knowledge to make their own rudimentary water filters. They will design, constrict, and test their water filters (APPENDIX M1D). The day is concluded with documentation in their engineering notebooks, which they are encouraged to take home and create other designs for tomorrow.

Day 5 is competition day. Given students' water filters from the day before, they are encouraged to create a new and improved design that follows a class design matrix. Afterwards, designs will be compared side by side and evaluated by the class to determine which design produced the best results. Students will spend some time writing in their notebooks why the winning design was the best and what they might do to their design to improve it.

The module is concluded with a final Kahoot! quiz that allows students to showcase their retention of the material. The quiz also allows the teacher to find areas of the module that may need more time or possible adjustment for their classroom. Below are some of the benefits of the CARE Team's educational solution.

*<u>Benefits and Value to the Educational Program</u>*

1. Low cost educational module
2. Inspires students to pursue STEM
3. Keeps students interested by utilizing healthy competition
4. Provides an easy-to-implement program for teachers that may not have access to a STEM educational module
5. Fun module designed to help inspire students at schools with low-retention rates
6. Adaptable program designed for all types of classes

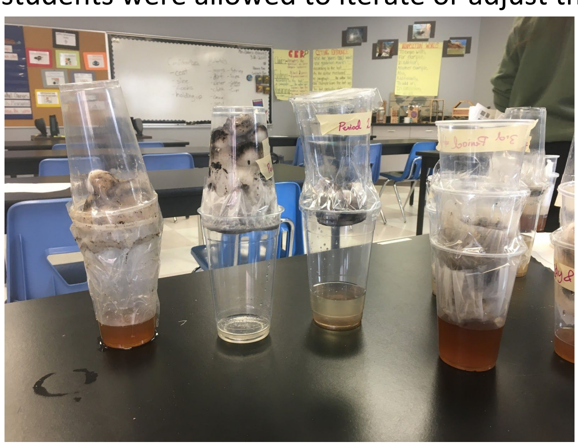
To ease the teaching process for Santa Rita teachers, all documents will be translated to Colombian Spanish. All teaching material will be formulated into a "Derechos Básicos de Aprendizaje" or "DBA" format familiar to the teachers of Santa Rita.

## Testing Phase Reflection

The main goal of the testing phase was to do various trials to show how the program could be run while identifying areas of misunderstanding or miscommunication present in the module's current instructions and plans. The team would also be able to gather feedback from the teachers participating in the testing. This was a great opportunity to determine if there are better ways of wording or explaining the module for easier understanding and efficiency. Once the modules are released, the team will no longer be the primary presenters and as such it is necessary to account for questions and issues that may arise during testing to better improve and iterate the program. For this reason, the team worked with Shelton Elementary School, Everitt Middle School, and Monument Academy to test the program. The team used a different approach at each of the schools to test the module's ability and performance variability.

At Monument Academy, the team sent the program materials to the teacher, and he bought his own supplies. He did the program independently with little guidance from the team. Overall, he spent one hour each day for 10 days implementing and adapting the program with his students. At Shelton Elementary School, the team had a more in-depth and in-person approach with the students. Three days were spent at the school with one STEM class to teach, build, and reflect on the material. This allowed for longer time frames spent per day. The team also worked with Everitt Middle School for one day. On this day, the team worked with four different classes for 45 minutes each. While the time spent was shortened, the kids were older and able to understand and grasp the concepts more quickly than the elementary schoolers. At both Shelton Elementary and Everitt Middle Schools, the materials were provided by the team.

The students at all schools were very creative and innovative in how they used the materials. Students used previous knowledge to predict what materials they would need and which order would be most effective to clean the water using different layers of sand, rocks, cotton balls, and other materials as seen in the photos below. The goal for the students was to make the cleanest water using their filters, then figure out why their filter did or did not. If time allowed the students were allowed to iterate or adjust their prototype.




Feedback for the project was mostly positive. The only negative feedback provided was that the project required quite a few materials to collect, but they were all easily accessible to the teachers and budget-friendly. The teachers particularly enjoyed the options and suggestions in case things couldn't be found or easily obtained. They also loved how hands-on and applicable to daily life the program was and how it was able to show their students the importance of water. The reading material discussed water as a resource and allowed the students to process why it mattered while the hands-on portion made the students think critically about how to best execute it using the scientific method. The group also found that leak prevention and sealing the prototypes proved to be a difficult task at times. This provided an additional, unanticipated lesson and was a great teaching point about properly sealing up pipes and why this is important at water treatment plants.

The work done by this year's CARE Team will also lay a solid foundation for next year's team to use as a springboard for further testing.

## Design Cost

The educational STEM module budget mainly consisted of different materials purchased for students to create the water filters. Materials were chosen based on what was used for similar water filtration activities performed by other schools and organizations. These supplies were purchased from Amazon, Wal-Mart, and Home Depot. When implementing this program in Colombia, the goal would be to purchase similar materials in the country from whatever items are available and most relevant. From an economic standpoint, the creation of kits that would include the different materials necessary to create the water filters could potentially be a source of income in the community. In Table 7 below, the materials list is included with corresponding prices in USD. This budget covered roughly five classes. Two of the classes had no more than ten students each while the other three had roughly 15-20 students each.

Table 7: Stem Educational Module 1 Budget

| **Item** | **Unit** | **Unit Cost** | **Total Units** | **Total Cost** |
|---|---|---|---|---|
| Folgers Classic Roast Ground Coffee | 48 oz. | $9.96 | 1 | $9.96 |
| Coffee Filters White | Pack of 100 | $3.80 | 2 | $7.60 |
| Cheesecloth | 36 $ft^2$ | $9.49 | 3 | $28.47 |
| Cotton balls | 500 balls | $6.99 | 3 | $20.97 |
| Large Plastic Cups | 100 pack- 24 oz. each | $16.99 | 1 | $16.99 |
| Large Plastic Cups | 50 pack- 16 oz. each | $6.17 | 4 | $24.68 |
| Gorilla Packing Tape | Pack of 1 | $8.97 | 3 | $26.91 |
| Super Glue | Pack of 12 | $6.60 | 1 | $6.60 |
| Food Packaging String | 100 yards | $6.99 | 1 | $6.99 |

| | | | | |
|---|---|---|---|---|
| Pure Organic Play Sand | 5 lbs | $16.48 | 1 | $16.48 |
| 0.5 cu. ft. Bagged Pea Gravel Pebbles | 48 lbs | $4.58 | 1 | $4.58 |
| Home Depot Play Sand | 50 lbs | $4.20 | 1 | $4.20 |
| Woodchips | 1 pint | $6.99 | 1 | $6.99 |

The total budget for the Stem Educational Module 1 was **$181.42**.

Funding was collected from a variety of sources: crowdfunding (Goldmine fundraising), grants, departmental funding, and money given from the senior design budget. The grants came from the SAIL office. The team received the Diversity, Inclusion, & Access Grant for initiatives that support those goals and the Community Grant which supported initiatives that would benefit the Mines community. An anonymous donor also contributed to the budget, with that funding simply labeled as "donation". This donor was separate from the crowdfunding donors. Table 8 below details the total funding used for expenditures.

Table 8: Santa Rita CARE Team Funding

| **Funding Source** | **Amount** |
|---|---|
| Goldmine Fundraiser | $1,392.00 |
| Donation | $3,420.00 |
| Capstone | $581.42 |
| SAIL | $500.00 |
| HE | $500.00 |
| International Office | $1,000.00 |
| **Total** | **$7,393.42** |

However, because the team was unable to travel to Santa Rita due to the COVID-19 pandemic, only $181.42 of the budget was actually spent. The remainder of the budget was to be used for travel expenses, in addition to funding from the McBride Program ($1,400) and the Multicultural Engineering Program ($1,500). However, these funds never got added to the budget because the travel was cancelled. Travel was anticipated to cost $1,200 per person for a total of three travellers; the total above would cover meals, lodging, transportation, and the airline tickets. The team also had planned to pay for the meals, lodging, and transportation of the college students from UNAL and Yesid Llanes, the team's Uniminuto Development Partner, while in Colombia.

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