

Introduction:

Today the best analytical minds of our developed countries throughout the world are faced with fourteen Grand Challenges for Engineering. These Grand Challenges have been determined by the National Academy of Engineering and include tasks such as reverse-engineering the brain, preventing nuclear terror, and making solar energy economical. Every task is a step towards making the world a better place for both our generation and every future generation. This project will help 4th and 5th graders relate to the Grand Challenge: provide access to clean water.

The world has an abundance of water, but it is not always located in the areas that need it. While some areas, like the Middle East, merely lack water; other areas do not have access to water that is safe for consumption. Today about 1 out of every 6 people alive cannot access adequate amounts of water and each day approximately 5,000 children die from diseases related to insufficient water sanitation. Developed countries have produced several methods to clean water including sanitation and desalination. These processes are, however, very expensive and most of the areas that lack clean, sanitary water are underdeveloped. Therefore, the world needs an economical solution to the Grand Challenge of providing access to clean water.

Summary:

Students in teams of 3 to 4 will explore this challenge of providing access to clean water along with the engineering process by designing and building a filter. They will have access to various materials that have been priced increasingly by their usefulness pushing the students to be creative in the pursuit of creating the cheapest filter.

Time:

The entire presentation should take approximately 30 minutes. This includes: 5 minutes for an introduction, 7 minutes of design time, 8 minutes of build time, and 10 minutes for testing and reflection

The Challenge:

Design a working filter for the cheapest price possible

Materials:

The table included below shows a suggested price list along with estimated prices. The total initial cost is estimated to be around \$50 using the materials we have suggested. This demonstration, however, can be repeated multiple times without requiring any additional costs which exceed \$5. This is dependent upon the number of groups you have and the materials they choose to use to build their filters. It should also be noted that it is possible that many of these materials are already available within your classroom and this is only a suggested list of materials. You may choose to substitute materials or include more or less materials for students to choose from.

Items Needed for Presentation		
Item	Quantity	Price
Clear Plastic Cups	80	2.48
Sand		3.98
Gravel		3.98
Suggested Materials		
Item	Quantity	Price
Coffee Filters	100	2.98
Paper Towel	60 sheets	6.02
Aluminum Foil	75 sq. ft.	3.48
Cotton Balls	400	3.68
Popsicle Sticks	300	4.97
Kleenex	160	1.57
Tape	108 ft	1.51
Rubber Bands	32	0.67
Yarn	≈100 yd	2.99
Pipe Cleaners	100	1.23
Scissors	3	3.44
Printing Paper	500 sheets	3.47
	Total:	46.45

Prices were found using Wal-Mart's website

Procedure:

Preparation (*Before Class*)

To prepare for this activity several items should be prepared ahead of time

1. Designate an area for materials and cut apart any materials that have predetermined lengths (eg. Aluminum foil, yarn)
2. Prepare several copies of the “Plan Your Filter” handout included in this packet. Make sure there are enough copies for each group to have one.
3. Determine how you wish to show the students Visuals 1 through 4 and make sure that this is prepared ahead of time
4. You should also prepare the “dirty water” prior to the presentation. Our suggestion for this dirty water is a little bit of sand, some gravel and small pieces of paper. Less than half of a cup of water is all that is necessary.

Introduction: (*5 minutes*)

In order to introduce the students to this problem we suggest using the following series of questions and visuals. You should, however, adjust this part to best suit your needs. Be sure to relate this to any relevant science background that your students may have on this topic and any related items that you have covered with your students.

1. Start by asking questions similar to the following: *Where did you get your water this morning? What did it look like? Do you know where it comes from?* This is meant to get the students involved and thinking critically immediately. It will ultimately help the students to relate to the information we provide them.
2. Show them a picture similar to the one labeled “Visual 1.” Visual 1 is a picture of an African well. This will contrast significantly with the idea that the students have of water. Follow up with this by asking students questions such as; *What if your water looked like this? Would you drink this?*
3. Explain to the students that in some places, like many countries in Africa, water like this is all they have access to. You can provide statistics such as 780 million people lack clean water which is more than 2.5 times the United States population. Many other statistics can be found through the teacher resources that are also included in this packet.

4. Now you should test the students critically thinking in this area by asking questions like the following: *How would you clean this water? Do you know how we clean our water? Why couldn't you do this in Africa?* Follow this up by explaining that many solutions to the clean water problem are too expensive to be utilized in these countries.
5. The above discussion should now be focused upon filters as that is the solution which relates to the project the students will have. Some of the cheapest and most economically viable solutions that modern engineers have developed are filters. These include clay pot filters such as those shown in Visual 2 and Visual 3 and water bottle filters shown in Visual 4. Students may have seen some of these water bottle filters.
6. We suggest showing the students these visuals and explaining to them how filters work. The basic science behind filters is that there are microscopic holes in the filter and only items that are smaller than these holes will pass through. So in our case, the water passes through while contaminants cannot.
7. Now, introduce the students to their challenge. It will be their challenge to build a working filter for the cheapest cost possible. They will be filtering water that contains sand, gravel, and paper shreds. The students will have approximately 10-12 materials to choose from each with a predetermined cost.

Design: (7 minutes)

This portion of the presentation will introduce the students to the engineering process. It will force them to think about and to plan their filter before getting their hands on any materials. Make sure that the students understand that the filter should be built on a plastic cup and then the dirty water will be poured through the filter so that clean water will be collected in the bottom cup. An image of this set up can be seen at the end of the report labeled as "Visual 5."

1. First, separate the students into groups of 3 to 4
2. To begin the design process hand out the paper that follows these instructions titled "Plan Your Filter" to each group. This is a handout that the students will use to design their filter and calculate how much it will cost.
3. You should explain to them that the first column lists all of the materials that are available to them and the second has the associated price. They should fill in the third column with how many of each material they want and calculate the final column by multiplying the

price and the quantity (the 3rd and the 4th columns). All of these values will be summed to calculate a grand total.

4. The students should also draw an illustration of their filter.
5. In order to emphasize the planning portion of this presentation, the prices of the materials will double after the initial purchase period.
6. At this point give the students approximately seven minutes to plan their project.
7. Be sure to circulate within the groups to encourage creativity and make suggestions. One of the largest issues that was present with the test groups is that they often purchased an excessive amount of materials so be sure to help the students make these estimates.
8. Be sure to announce when design time is over
9. Ask each group to send one representative to retrieve the materials bringing with them their materials sheet.
10. Hand out the appropriate materials. We suggest having those materials that need cutting, such as yarn and tape, pre-cut but it is certainly not necessary.

Build: (8 minutes)

During this portion of the demonstration students will get to produce their design.

1. Once all the students have the materials they decided upon (including a plastic cup) announce the beginning of the building time which will last for 8 minutes.
2. Circulate within the groups to help the students with any necessary problem solving
3. Provide the students with any materials that they decide they need in addition to what they planned for. Make sure that any additionally purchased materials are added to their cost at half the price.
4. Announce the end of the building period. If all of the groups finish before the eight minutes are up go ahead and proceed to the next section.

Testing/Reflection: (10 minutes)

This portion will allow the students to show off their design and watch their filter's performance. It will also include an analysis and reflection upon their creation and any possible

improvements. Students will also elect a “best filter” by comparing cost, effectiveness, and efficiency. It is highly suggested that at this point you once again relate the experience to material students have already covered or any material you plan to cover in the near future.

1. Ask each group to send up one representative who will explain and test their filter.
2. Once all groups have a member up front, ask each to take a moment and explain their filter, most importantly what materials they used and what was their total cost.
3. Next, ask the students to all demonstrate their filters at the same time by pouring the “dirty water” through it. We suggest doing this over some type of pan, bucket or tray so that any spills are easily collected. This setup is demonstrated in Visual 6.
4. As the water is running through the filters, make comments about those that are working the fastest or most efficiently
5. Next, ask questions to both individual group members and to the class as a whole about how well they think each filter worked. Ask questions like: *Which filter worked the best? Which was cheapest? Would you drink this water now? Which filter was the fastest?*
6. Now, ask the students about what changes they would make to their filter.
7. At this point you should lead a discussion about tradeoffs. Talk about how some filters although cheaper may be much slower, is it worth it? Discuss which filters could be used repeatedly and what impact this may have on which filter you chose to use.
8. Conclude by both repeating how important this type of engineering is to certain areas of the globe and by relating this material back to things they have learned or will learn in class.

Plan Your Filter

Material	Price (\$)	Quantity	Cost
Pipe Cleaner	1		
Cotton Balls	2 for 1		
Yarn	3 per meter		
Popsicle sticks	1		
Tape	1 per 10 cm		
Printer Paper	2		
Kleenex	4		
Aluminum Foil	5 per ft. ²		
Scissors	3		
Rubber Band	5		
Paper Towel	15 per sheet		
Coffee Filter	20		
Grand Total:			

Draw Your Filter!

Visuals



Visual 1

Picture taken by Unicef of African women obtaining water from an unsafe well



Visual 2

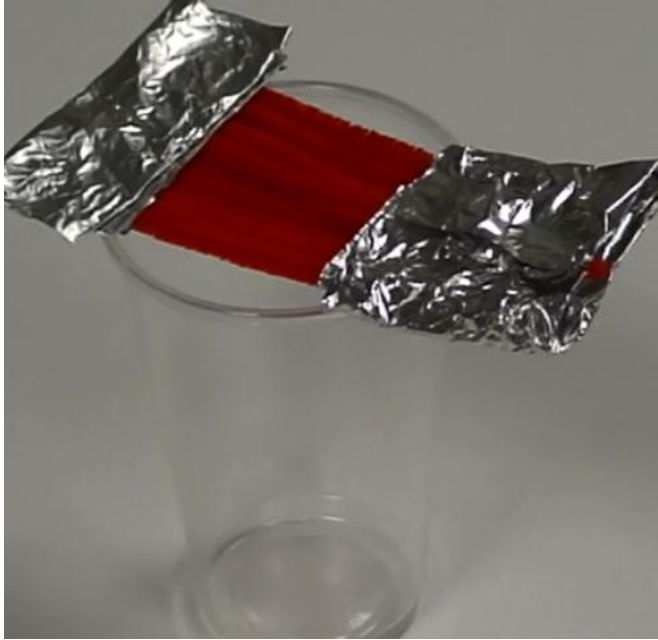
A ceramic water filtered being prepared for use. This view shows the bulk of the filter.



Visual 3
The ceramic filter in Visual 2 in use



Visual 4
A Lifesaver water bottle. This bottle utilizes filtration and other water treatment techniques to sterilize water.



Visual 5

This is an example of a finished filter. The filter should be built so that it can sit on top of a plastic cup.



Visual 6

This is a picture of the suggested set up for testing.

Teacher Resources

This source is the engineering grand challenges website. It gives a good overview of the grand challenges of engineering, in particular to this site, the clean water challenge. It is a good starting point to learn about the conversation that has started as a result of the grand challenges of engineering

<http://www.engineeringchallenges.org/cms/8996/9142.aspx>

This page has some interesting statistics to show the scope of the clean water problem. It has an interactive map that shows how many people suffer from the shortage of clean water. It is good to get an idea of the big picture when it comes to the clean water grand challenge. It is also a page that might be worth showing to students if time permits.

<http://water.org/water-crisis/water-facts/water/>

This web page gives another viewpoint to the grand challenge from the viewpoint of us as water stewards. An account is necessary to view this article, but it is free and has articles on other interesting topics. It is a National Geographic article.

<http://environment.nationalgeographic.com/environment/freshwater/freshwater-crisis/>

This next link is a youtube video entitled "A glass full of water: Point-of-use solutions" by Cheney Tsai. This video explains the problem of current water treatment systems, and shows solutions in a visual manner. The video also gives an insight into the reasons for point of use water treatment, the strategy employed by our demonstration.

<http://www.youtube.com/watch?v=q7MxsDmGEVY>

The next source is a journal article from the American Journal of public health. It emphasizes the importance of Point-of-Use water treatment systems in the solving of the grand challenge of clean water.

E. Mintz, J. Bartram, P. Lochery and M. Wegelin, "Not Just a Drop in the Bucket: Expanding Access to Point-of-Use Water Treatment Systems," *American Journal of Public Health*, vol. 91, no. 10, pp. 1565-1570, 2001.

The following video is a TED talk that demonstrates a newer strategy for the treatment of dirty water. It gives a background for the issue and a new viewpoint for the approach of the challenge.

M. Pritchard, "YouTube," TED Talks, 4 August 2009. [Online]. Available:
<http://www.youtube.com/watch?v=rXepkIWPhFQ>. [Accessed 16 January 2014]