

I. Fire Brigade

Imagine a new fire fighting material has been developed that is highly effective in putting out fires quickly without the additional property damage that comes from water or the environmental impacts of traditional fire fighting chemicals. Unfortunately, this revolutionary new technology cannot be delivered to a fire with the typical devices. The fire department is looking for a new device that will allow them to deliver the fire fighting material to the fire safely. (Note: No real fire is used in this challenge.)

Grade Levels: 3-8

Educational Outcomes:

- 1) Students will understand how a community works together to protect people from fire.
- 2) Students will learn about scientific principles needed to make a functional tool.
- 3) Students will have first-hand experience with design and the engineering process.
- 4) Students will work in teams to creatively solve problems as they design and build a device to meet the stated challenge.

Estimated Time: 2 sessions: 40 – 60 minutes each (note: the first session can stand alone)

- Introduction: 5-10 minutes
- Building: 20-25 minutes
- Sharing: 10-15 minutes
- Clean-up: 5 minutes

Science Standards Connections:

The following is a selection of CA State Science Standards that can connect this Design Challenge activity to your existing curriculum.

Grade 3 – Physical Sciences:

- 1c. *Students know* machines and living things convert stored energy to motion and heat.
1d. *Students know* energy can be carried from one place to another by waves, such as water waves and sound waves, by electric current, and by moving objects.

Grade 6 – Physical Science:

- 3a. Students know energy can be carried from one place to another by heat flow or by waves, including water, light and sound waves, or by moving objects.

Grade 7 – Physical Principles in Living Systems (Physical Science):

- 6i. *Students know* how levers confer mechanical advantage and how the application of this principle applies to the musculoskeletal system.

Grade 8 – Forces:

- 2e. *Students know* that when the forces on an object are unbalanced, the object will change its velocity (that is, it will speed up, slow down, or change direction).
2f. *Students know* the greater the mass of an object, the more force is needed to achieve the same rate of change in motion.

All grades - Investigation and Experimentation: Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations.

Extra Science Standards:

This Design Challenge can be changed or adapted to cover other standards depending on how you incorporate specific content or skills into the challenge constraints or requirements. For example, if you require students to use magnets or electrical components in their design, you could touch on the 4th grade standard on electricity and magnetism. See the Extensions and Variations section for additional ideas.

Grade 3 – Life Science:

3c. Students know living things cause changes in the environment in which they live: some of these changes are detrimental to the organism or other organisms, and some are beneficial.

Grade 4 – Physical Science:

1. Electricity and magnetism are related effects that have many useful applications in everyday life.

Grade 4 – Life Sciences:

2c. *Students know* decomposers, including many fungi, insects, and microorganisms, recycle matter from dead plants and animals.

Grade 6 – Resources:

6. Sources of energy and materials differ in amounts, distribution, usefulness, and the time required for their formation.

Grade 7 – Structure and Function in Living Systems:

5c. *Students know* how bones and muscles work together to provide a structural framework for movement.

Grade 7 – Physical Principles in Living Systems:

6h. *Students know* how to compare joints in the body (wrist, shoulder, thigh) with structures used in machines and simple devices (hinge, ball-and-socket, and sliding joints).

Tech Museum Gallery Connections: Innovation: Virtual Design – Design a Bike, Design & Ride a Rollercoaster. Life Tech: Beyond our Limits – Body Enhancements.

II. FIRE BRIGADE: ADVANCED PREP AND SET-UP

Student materials:

Materials can be limiting or inspirational to students! Have a wide variety of materials to promote a diversity of solutions. For example, if you have been studying electronics – provide a variety of batteries and motors or lights and require students to use them in their solution (see Extensions and Variations).

General supplies available to everyone (examples below; actual materials may vary):

- Wood dowels or similar plastic rods
- Elastic
- String
- Drinking straws
- Cardboard/heavy paper
- Twist ties
- Springs
- Take-out food trays or boxes
- Cups (all shapes / sizes; paper or plastic)
- Masking tape (limit to 8 inches)
- Pipe cleaners
- Clothespins
- Craft sticks
- Binder clips
- Plastic Bags
- Plastic-ware

"Recycled items" are really useful: old mouse pads, wood scraps, boxes, cardboard rolls from paper towels, toilet paper, or gift wrap; "strawberry baskets", and more!¹

Tools or adhesives that might also be useful:

- Scissors
- Low-temperature hot glue gun and glue sticks
- Hole punch
- Craft glue

Instructor materials:

- The challenge and constraints should be visible: written on board, overhead, etc.
- Water Wiggly – the oblong water-filled toy that slips out of your hand like a bar of soap. Have multiples so many teams can try at once, (available at many gift shops; there are also many resources on the internet). The different sizes present their own unique challenges. Feel free to work with a variety of sizes.
- Fire target – this can be a bucket or trash can with some colored paper flames on the sides.



Sample Water Wigglies
(large and small)

¹ RAFT (Resource Area For Teachers) is a great place in San Jose, CA to find these items and many more. Visit their website for more information (www.raft.net). You can also try American Science and Surplus (www.sciplus.com) for interesting and inexpensive materials.

III. FIRE BRIGADE: LESSON PLAN

Introduction

In any industry, engineers and designers work to improve the tools available to them. For fire fighters, their primary concern is to extinguish the fire quickly, keeping both themselves and the people living nearby, safe. Unfortunately, the water or fire retardant chemicals they use can cause significant property and environmental damage as well.

A. Design Challenge #1: Build a Better Bucket

Challenge Scenario: A revolutionary new fire retardant material has been developed that will not damage property like water and is safe for the environment. However, its unique properties make it impossible to deliver to a fire with the traditional tools available to fire fighters.

Challenge: Design a device that will pick up the fire retardant material (a water wiggly toy), and deposit it on the simulated fire, while keeping you safe from the fire.

Challenge set up: Have a trash can (or other container) with colored paper flames on the side to simulate a fire.

Constraints

- You may not use your hands to pick up the fire retardant or deliver it to the fire; the device must be what comes in contact with the fire retardant. You *may* operate the device, however.
- You must operate the device from a standing position. (You should be able to respond to changes in the fire quickly.)
- You must remain at least 3 feet away from the fire at all times for safety. Your building materials are all fire proof.
- You may not break the fire retardant container.

Extensions and Variations

- The device must be small enough to fit in your pocket or be carried easily so it will be easy to store between fires.
- Device must be able to pick up multiple fire retardant containers at one time, but deliver them one at a time.
- Design a jumbo device to deliver large containers of fire retardant to large fires.
- Use this Design Challenge in connection with lessons on forest succession, thermodynamics, or environmental protection.
- Make your device at least partially automated using motors, gears, batteries etc.

Facilitator Notes:

Bucket Brigades were one of the first organized methods of fighting fires where leather buckets full of water would be passed up a line to the fire and then back to the water source down another line. Bucket Brigades can be traced back to the American colonies as early as 1648 in New Amsterdam (New York).

Demonstration and Reflection:

Demonstration: Have teams demonstrate their device for the group. If students have not completed their device, ask them *how the device would have worked*.

Reflection: Each team will explain their design strategy and how their device meets the challenge constraints. Instructor should ask leading questions and point out other facets of the student's designs (e.g., simple machines), including similarities and differences with other devices, how various teams solved a similar problem in similar/different ways, etc.

Teaching Points:

- There is more to designing a device than building it. You must consider the resources available and the limitations of a design. Brainstorming, testing and teamwork are also important.
- Complex problems and machines can be simplified by looking at smaller aspects of them.
- You can protect yourself in dangerous situations like a fire with a little forward thinking.

Questions to encourage teaching points:

- Can the problem be broken down into smaller, more manageable pieces?
- Ask about specific components of the device, what they are for, how they could be improved, etc.
- How do the physical properties of the water wiggly affect your device? Can you use those properties to your advantage?
- Could your device replace the fire extinguisher people have in their kitchens, where the person may be elderly or have a broken arm?
- If you had more time or different supplies what would you add, change, or do differently?

Clean up: Reduce! Re-use! Recycle!

Only throw away items that cannot be re-used. All items should be returned to the appropriate bin/basket. Make sure items accidentally dropped on the floor are cleaned up. Students may keep their devices, unless the teacher plans on keeping them for the second part of the challenge.

B. Design Challenge #2: Volunteer Fire Brigade

Challenge Scenario: A small town relies on the help of their neighbors to battle fire in their community. They have chosen to use the new fire retardant material and the set of delivery devices that has been developed by a top team of engineers (that would be the class). The town council has determined that a traditional bucket brigade would be the most effective way for the townspeople to fight fires in their town.

Facilitator Notes:

A study by the USGS found that the fire retardant chemicals and fire suppressant foams used in fighting wildfires has a mild or moderate impact on the vegetation in the area. However, they have significant negative impacts on aquatic plants and animals.

Incorporate a peer review time into the lesson plan. Any good innovation benefits from review from other innovators. The fresh set of eyes can often help see solutions to difficulties or possible improvements that the original designer does not see. An example of a peer review is in the appendix.

Challenge: Modify your device or design a new device that will receive the fire retardant material (a water wiggly toy) from another device and pass it along to the next device. The first device in line should pick up the fire retardant and the last one should deposit it on the simulated fire, while keeping everyone safe from the fire.

Challenge set up: Have a trash can (or other container) with colored paper flames on the side to simulate a fire. If the class is large, it may be better to divide them into two groups.

Constraints

- You may not use your hands to pick up the fire retardant, pass it to the next device, or deliver it to the fire; the device must be what comes in contact with the fire retardant. You *may* operate the device, however.
- You must operate the device from a standing position. (You should be able to respond to changes in the fire quickly.)
- The all teams must remain at least 3 feet away from the fire at all times for safety. Your building materials are all fire proof.
- You may not break the fire retardant container.
- It will take multiple containers of the fire retardant to extinguish the fire. The teacher should determine how many.
- All teams must work together to decide the best order for the devices in the brigade, and how to adapt each device to the new challenge through the peer review process. (See addendum)

Extensions and Variations

- Write instructions on how to use your device. See if other classmates can understand the directions and be successful with your device.
- Have teams trade devices to see if someone who is untrained (like a towns person) can operate the device.
- Extinguish the fire as quickly as possible.
- Device must be able to pick up multiple fire retardant containers at one time, but deliver them one at a time.
- Create an obstacle course so the fire retardant has to be passed under some things, over others, etc.
- Turn the line into a circle and play Hot Potato!

Demonstration and Reflection:

Demonstration: Have the class decide the best order for teams to line up in the brigade line. Place the necessary number of water wiggly near the first team. For testing trials, pass one wiggly at a time so teams can watch what happens and learn from the test. In the final demonstration, the first team can start passing the next wiggly right away.

Reflection: Discuss with the class how their devices worked together and how the brigade activity impacted their designs. Instructor should ask leading questions and point out how team dynamics changed or stayed the same with the class essentially working on one team.

Teaching Points:

- Changing the purpose of a device, even slightly, can have significant impact on its design.
- Engineers come together often to look at their designs and get suggestions to solve problems and make improvements.
- Complex problems and machines can be simplified by looking at smaller aspects of them.
- You can protect yourself in dangerous situations like a fire with a little forward thinking.

Questions to encourage teaching points:

- Can the problem be broken down into smaller, more manageable pieces?
- Ask about specific components of the device, what they are for, how they could be improved, etc.
- How do the physical properties of the water wiggly affect you device? Can you use those properties to your advantage?
- How do the various devices differ? Can those differences or similarities be used to your advantage?
- If you had more time or different supplies what would you add, change, or do differently?

Clean up: Reduce! Re-use! Recycle!

Only throw away items that cannot be re-used. All items should be returned to the appropriate bin/basket. Make sure items accidentally dropped on the floor are cleaned up. Students may keep their devices.

IV. FIRE BRIGADE: TEACHER NOTES

Glossary & Concepts:

- Fire Retardant: a substance that prevents combustion and can therefore be used to slow the spread of a fire. It is not applied directly to a fire.
- Fire Suppressant: a substance that is applied directly to a fire in order to “suppress” the flames, but not necessarily to prevent the spread of the fire.

Pre- and post- activities:

- Marketing: Have students create a product name and advertising materials to sell/promote their device to potential customers.
- Product review: Have students test multiple devices and write compare/contrast reviews.
- Create a class webpage to showcase the devices, their reviews, and more.
- Challenge another class to a fire-fighting contest!

Resources:

- *Conceptual Physics for Parents and Teachers: Mechanics* by Paul Hewitt. Focus Publishing/ R. Pullins Company, Newburyport, MA. 1998.
- *Exploring Energy with Toys* by Beverley A. P. Taylor. Terrific Science Press, Middletown, OH, 1998.
- *The Inventa Book of Mechanisms* by Dave Catlin. Valiant Technology Ltd., London, England, U.K., 1995.

Web Resources:

- Fire Fighting History
<http://www.antiquetalk.com/bucket.htm>
<http://www.firehouse.com/magazine/american/colonial.html>
- Governmental fire fighting sites (US and Canada)
<http://www.npwrc.usgs.gov/resource/othrdata/fireweb/fireweb.htm>
http://www3.gov.ab.ca/srd/wildfires/fpd/fw_ws_ao_fr.cfm

V. APPENDIX

Peer Review

Purpose: A peer review session is intended to give teams the opportunity to discuss their approach with another team – explain their idea, discuss pros/cons, ask for input or help with challenging parts, etc. This can also be done within a team in order to hear all of the opinions of the members. In addition, these sessions will ensure that each team has done “market research” i.e., learning about another team’s approach to the same problem. Students can conduct peer reviews with their friends, siblings, or other students in their school or community group.

Setting norms: Prior to the review, it may be important to discuss “constructive criticism” and how teams can share ideas with each other. Set expectations around positive interaction (not “this is a stupid idea”!), focus on questions and comments that may help each other, etc.

Design Review: Ample time should be allotted for each team to share their ideas, solicit comments, and discuss them. The “Design Review Questions” handout that follows is a good guideline for this process. In the end, take some time to review the comments and decide how to use the information. Record your decision on their peer review form, and add it to any other documentation from this Design Challenge.

If teams do not know what to talk about at the beginning, suggest they use the Design Review Questions handout to get them started.



Design Review Questions

Date: _____

Peer Review for (name of team): _____

Reviewed by (name of team/individual): _____

Reviewer's comments:

What do you think are the advantages of this solution?

What do you think are the disadvantages of this solution?

What is one idea that you (peer reviewer) can offer the team to help improve their design?

For the team being reviewed:

What will you do with the information you learned from this design review?