Students demonstrate their knowledge of Newton’s 1st Law of Motion as they engineer a new method for putting out fires. As they iterate through this design challenge, they gain firsthand experience in the design process.

**Grades 3-6**

**Estimated time:** 70 minutes (Optional: 2 sessions)

**Student Outcomes:**

1. Students will be able to identify the factors that influence the evolution of tools over time.
2. Students will be able to describe their design choices based on scientific concepts during a peer review process.
3. Students will be able to utilize the three step design process to meet an engineering challenge.

**Next Generation Science Standards**

*Grade 3-5: Engineering Design 3-5-ETS1-1, 3-5-ETS1-2, 3-5-ETS1-3*

*Grade 6: Engineering Design MS-ETS1-1, MS-ETS1-2, MS-ETS1-3, MS-ETS1-4*

**Common Core Language Arts-Speaking and Listening**

*Grade 3: SL.3.1b-d, SL.3.3, SL.3.4a*

*Grade 4: SL.4.1b-d, SL.4.4a*

*Grade 5: SL.5.1b-d, SL.5.4*

*Grade 6: SL.6.1b-d*

**Vocabulary:**

*Familiarity with these terms and concepts will enhance students’ experience in the activity*

- **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.

**Resources:**

- The Evolution of PPE: An article on FirefighterNation written by one of their staff on how Personal Protective Equipment for firefighters has changed over the years. It breaks the information into categories based on technological and need-based changes. [www.firefighternation.com/article/firefighter-safety-and-health/evolution-ppe-0](http://www.firefighternation.com/article/firefighter-safety-and-health/evolution-ppe-0)


[https://www.thetech.org/educators/design-challenge-learning](https://www.thetech.org/educators/design-challenge-learning)
Design Challenge Process:
The Design Challenge Process is designed so students reinforce their science, mathematics, social studies, and language arts content knowledge, through an open-ended process that results in an original, team-driven solution. Students are expected to take responsibility for assessing their own progress and incorporate peer feedback as they conceptualize and redesign their projects.

The process consists of three interconnected steps:

**Conceptualize**
- Identify problem, materials, and constraints
- Brainstorm ideas and possible solutions

**Construct and Test**
- Select a solution
- Design and construct
- Prototype
- Redesign or modify
- Retest

**Acquire Knowledge**
- Research
- Share solutions
- Reflect and discuss

Through the try, fail, learn approach, students develop skills and habits of mind of Silicon Valley innovators: creativity, problem solving, design, collaboration, leadership, risk-taking, perseverance, and learning from failure.

Materials:
Materials can be limiting or inspirational to students! Have a wide variety of materials to promote a diversity of solutions. “Recycled items” are really useful: old mouse pads, wood scraps, boxes, cardboard tubes, strawberry baskets, etc.

Class Supplies to Share:
- Wood dowels
- Plastic dowels
- Elastic
- String
- Drinking straws
- Cardboard
- Cardstock
- Twist ties
- Springs
- Take-out food containers
- Cups (various sizes, and materials)
- Masking tape (8in max)
- Pipe cleaners
- Clothespins
- Craft sticks
- Binder clips
- Plastic bags
- Plastic-ware
- Scissors
- Low-temperature hot glue gun and sticks
- Hole punch
- Craft glue

Testing Supplies:
- Water Wiggles (various sizes)
- Buckets/trash cans
- Paper flames

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Lesson Plan:

Introduction (10 minutes)

1. In any industry, engineers and designers work to improve the tools available to them. Can you come up with a tool that has evolved to meet new constraints? How did it change? Why were these changes made?
2. Fire fighters have a tough job. They must extinguish fires, and do it quickly, while keeping themselves, other people and animals, personal property, and the environment safe. Unfortunately, the water or fire retardant chemicals they use can cause damage to property and the environment.
3. What tools do fire fighters have in order to put out the fire? How do you think water, other fire retardant chemicals, and fire fighter tools make it difficult for firefighters to meet all the expectations of their job? What are some of your ideas for solving these problems?

Design Challenge #1: Fire Brigade (20 minutes)

1. Introduce the 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.
2. Introduce the Challenge: Design and build a device that will pick up the fire retardant material and deposit it on the simulated fire.
3. Introduce the Constraints:
   - You may not touch the fire retardant with your hands at any time.
   - Your device must be operated from a standing position.
   - The operator must remain at least 3 feet away from the fire at all times.
   - You may not break the fire retardant capsule.
4. Build: Give students about 20 minutes to build. Instructor should ask open-ended questions to help guide students through the design process, but should also allow students space to tinker. Students should be encouraged to test and iterate their device during the build period.

Demonstration and Reflection (10 minutes)

1. Demonstration: Have teams demonstrate their device for the group. If students have not completed their device, or their device did not function as expected, ask them how the device would have worked.
2. Reflection: Each team will explain their design strategy and how their device meets the challenge constraints. The 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 a similar/different way, 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.
   - Questions to Encourage Teaching Points
     - Can the problem be broken down into smaller, more manageable pieces?

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Fire Brigade
Design Challenge Learning

- Ask about specific components of the device. Ex.: What are they for? How can it be improved? Why did you choose to do that?
- How does 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?
- If you had more time or different supplies what would you add, change, or do differently?

Extensions for Design Challenge #1: Fire Brigade

1. Repeat the challenge but add to the constraints that the device must be small enough to fit in your pocket or be carried easily.
2. Repeat the challenge but add to the constraints that the device must be able to pick up multiple fire retardant containers at one time, but deliver them one at a time.
3. Set an expectation that the device must be capable of delivering large amounts of fire retardant to the fire.
4. Connect this design challenge to lessons on forest succession, thermodynamics, or environmental protection.
5. Add materials and constraints that connect with current science units such as requiring motors, gear, batteries, or lights be added if the current unit is on electricity.
6. Post-activity: Have students create a product name and advertising materials to sell/promote their device to potential customers.
7. Post-activity: Have students test multiple devices and write reviews that compare and contrast the tested devices.

Design Challenge #2: Bucket Brigade (20 minutes)

1. Introduce the 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 (the class). The town council has determined that a traditional bucket brigade would be the more effective way for the townspeople to fight fires in their town.
2. Introduce the Challenge: Modify your device or design a new device that will receive the fire retardant material (a Water Wiggly) from another device and pass it along to the next device. The first device in line should pickup the fire retardant and the last one should deposit it on the simulated fire.
3. Introduce the Constraints:
   - You may not touch the fire retardant with your hands at any time.
   - You must operate the device from a standing position.
   - All device operators must be at least 3 feet away from the fire.
   - You may not break the fire retardant capsule.
   - You must transport x fire retardant capsules to the fire. (note: the instructor should determine how many Water Wiggles must be transported.)
   - You must use the peer review process in order to determine the best order for the devices.
4. Build: Give students about 20 minutes to build. Instructor should ask open-ended questions to help guide students through the design process, but should also allow students space to tinker. Students should be encouraged to test and iterate their device during the build period.

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Demonstration and Reflection (10 minutes)

1. **Demonstration:** Have the class decide the best order for teams to line up in the brigade line. Place the necessary number of Water Wiggles near the first team. For testing trials, pass one wiggle 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 Water Wiggly right away.

2. **Reflection:** Discuss with the class how their devices worked together and how the brigade activity impacted their designs. The 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.
   - **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 does the physical properties of the Water Wiggly affect your 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?

Extensions for Design Challenge #2: Bucket Brigade

1. Write instructions on how to use your device. See if other classmates can understand the directions and be successful with your device.
2. Have teams trade devices to see if someone who is untrained (like a towns-person) can operate the device.
3. Place a constraint on how long the team can work to move Water Wiggles.
4. Repeat the challenge but add to the constraints that the device must pick up multiple fire retardant containers, but deliver them one at a time.
5. Repeat the challenge but add obstacles that the fire retardant must be passed under or over.
6. Play Hot Potato using the devices.
7. Create a class webpage to showcase the devices, their reviews, and more.
8. Challenge another class to a fire-fighting contest!
Peer Review
A guide

**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 their 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 guide 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.

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Design Review Questions

Hand Out

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 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?