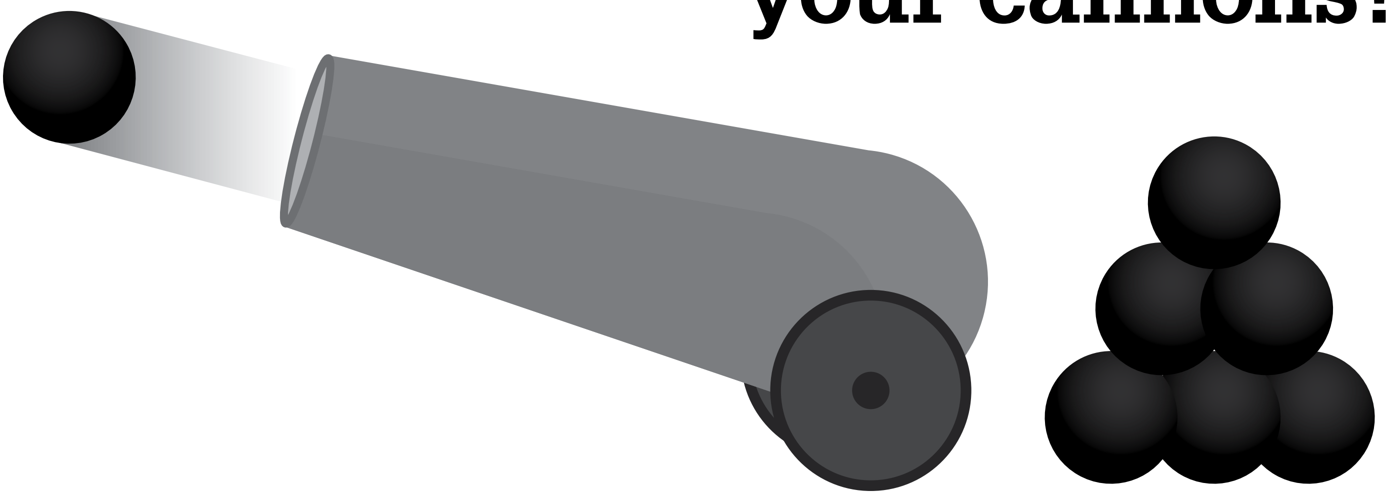
Mary C. Enderson

Ready, aim, fire your cannons!



Have you ever thought about what it would be like to fire a cannon? How far do you think a cannonball can go when you shoot it out of a cannon? Can you make a cannonball go a certain distance? Are some cannons better than others? If so, in what ways?

These are just a few questions that teachers can ask students to think about as they implement a STEM activity—building an air cannon—in their math classroom. In what follows, readers are presented with an investigation grounded in STEM concepts that elementary and middle school teachers carried out to think about ways of implementing STEM activities into their instruction.

Air Cannon is an activity developed around the science concept of force, or energy, and is introduced on PBS's Design Squad Nation (WGBH Foundation 2008). This PBS feature promotes the engineering principles of design for young learners and often presents activities one can create with everyday types of materials. This particular activity has great potential for elementary school students in grades 3–5 in that it uses principles of science (force/energy), technology and engineering (building the air cannon), and mathematics (measurement and data). Such an activity can be worked into classroom instruction to "hit" on any one specific area or can be fully integrated to meet all STEM areas. One version of carrying out the Air Cannon investigation targets mathematics concepts specific to the elementary levels and is the focus of this article.

Estimating and measuring length, representing and interpreting data

The Common Core (CCSSI 2010) mathematics concepts promoted in this investigation focus on (1) estimating and measuring lengths in standard units and (2) representing and interpreting data. These topics receive attention across grades 3–5 as well as support the Common Core's Standards for Mathematical Practice (SMPs), which include the following:

- Make sense of problems and persevere in solving them (SMP 1)
- Construct viable arguments and critique the reasoning of others (SMP 3)
- Model with mathematics (SMP 4)
- Use appropriate tools strategically (SMP 5)
- Look for and make use of structure (SMP 7)

Connecting content with practices allows a teacher to present rich situations in which students can engage in doing mathematics while using principles of science, technology, and engineering. Students gain experience in estimation (comparing different launches—how much farther one cotton ball goes than another), measurement (actually using

metersticks and tape measures to measure distance of launches—in both the metric and English system), and data collection (displaying launch data in frequency tables, graphs, and measures of central tendency).

Scientific inquiry, engineering design, problem solving

Before carrying out this exploration, students need exposure to scientific inquiry, the engineering design process, and problem solving. Each one of these methods possesses specific actions and reactions, but all are related in the way the investigative process occurs. Students are presented with a task, think about approaches toward working through the task, carry out strategies to resolve it, reflect on and evaluate the product, and finally determine if they have more work to do. If so, they carry out the process again. If not, they report on findings that best answer or solve the problem under investigation. These steps are all part of what scientists, engineers, technology experts, and mathematicians do in their work with real problems. This activity is integrative and addresses standards in each STEM area. Although these areas are all important for students to experience, this article focuses on the Common Core State Standards for Mathematics (CCSSM) and the Standards for Mathematical Practice (SMPs) (CCSSI 2010) for teachers to consider.

The first phase in this investigation is to have students think about building their own air cannon device using simple, everyday materials. Before implementing the investigation, have students collect and bring in paper and plastic cups, Pringles® potato chip cans (long and short), little cookie snack containers, plastic bags (newspaper and baggie size), duct tape or packing tape, and cotton balls or puff balls. These everyday materials are often found in most homes or after-school programs (see **fig. 1**). After materials are in place for classroom use, introduce the investigation to students so they may think about ways to design the air cannon. Implementing the engineering design process is a familiar technique for students (see the **sidebar** on **p. 504**). This design process is well known among science and engineering communities. Students begin with a problem, brainstorm ways to approach it, sketch possible designs, build the best design, test and evaluate

FIGURE 1

This investigation requires everyday materials typically found in most homes or after-school programs: paper and plastic cups, potato chip cans (long and short), snack containers, plastic bags, tape, and cotton balls.

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it, redesign components that would make “it” a better fit, and build the model again. After students have built their best product, they share their findings. The processes of building, testing and evaluating, and redesigning are cyclic. For this particular investigation, the teacher follows the steps of the engineering design process and provides students with time and guidance at each phase.

Promoting mathematical concepts

As students engage in the engineering design process, promoting the mathematical concepts is a crucial step for teachers to take so that students will recognize connections between real problems and concepts taught in school. Estimation and measurement, along with representing and interpreting data, are key areas of focus for this investigation. Teachers indicated that they like to have their students predict or guess—before carrying out the mathematical portion of this investigation—what they believe will happen with the firing of the cannons. In other words, how far will the cotton ball go when I shoot it out of my air cannon?

The engineering design process

The following design process is well known in science and engineering communities. Implementing the engineering design process is a familiar technique for students.

Steps in the process

1. Identify the problem
2. Brainstorm
3. Design
4. Build, test, and evaluate; redesign
5. Share solutions

1. Problem: Build an air cannon to shoot a cotton ball as far as possible.
2. Brainstorm: Give students time to brainstorm key features of the cannons and sketch ideas in their engineering design notebooks on what the cannons might look like. Have them think about what a launch means. How would I shoot the cotton ball out of the hole in my container? How can I have my launch go as far as possible—use a bigger bag, a bigger container, a bigger cotton ball, more air in the bag (how might I increase the amount of air in the cannon), a harder push to the bag to shoot the cotton ball out (is there another way to apply force to expel more air from the cannon)? All these ideas should be part of the brainstorming process.
3. Design: Have students think about ways to build the cannons, given the materials provided in the classroom.
4. a. Build: Students select materials for building their own air cannon and begin the construction phase. Using the best prototype sketch, students construct or build the cannon.
   b. Test and evaluate: Test the cannon. Could it launch a cotton ball? Evaluate its functionality.
   c. Redesign: Consider the need to redesign it. Could I build a better cannon? What will make the launch of the cotton ball go farther?
   d. Back to the build step: Rebuild it if improvements can be made. This process continues until one creates the best model possible that meets the conditions of shooting the cotton ball as far as possible. Go through steps 5 and 6 until one believes that one has a good contender (see **fig. 2**). After students have time to cycle through steps 5–7 twice, the teacher pairs them (or forms groups of three) to allow students an opportunity to discuss individual findings. At this point, students should do the next step.
5. Share solutions to look for the best model to fit the given conditions in the search for the "best" air cannon.

Components that students may need to consider include the size of container used to build the cannon, the circumference of the cup or container, the size of the hole in the cup or container, the size of the bag, and the force of the push (to the bag) to launch the cotton ball. After making predictions, students should have several opportunities to "fire their cannons." This allows them to see how close they were with their predictions before working with the pertinent mathematics concepts.

At this point, estimation and measurement of various cannon launches take center stage. Using standard units of measurement (metric and English) allows students opportunities to measure real distances and, in the process, to make conversions among units while making observations about how to improve on the air cannon model to shoot a greater distance. Finally, data analysis includes collecting measurements for various launches of the same container for numerous runs to see how far the cotton ball goes. Students can use these data for studying the mean, median, and mode as well as ways of representing and graphing results. See **figure 3** for a handout that may be used to guide the Air Cannon investigation. CCSSM (CCSSI 2010) progresses into working with graphing points on a coordinate plane to solve real-world and mathematical problems for grade 5. The teacher could organize several grids marked off on a classroom floor made of square tiles to use as students fire their cannons, allow the cotton ball to land, and then note the ordered pair on the coordinate grid. Problems related to these points could be generated as students move toward studying algebra and the concept of rise over run for developing slope and linear measurement.

Constructing an air cannon engages students in building models, analyzing the work

of others, generating new questions to explore, and working with mathematics concepts in a nontrivial way. At the elementary school level, identifying activities that target multiple areas simultaneously and generate excitement for student learning and sense making are important considerations for teachers. In addition to the STEM focus, opportunities exist for connecting to other disciplines, such as language arts, music, and art. Because pirate stories typically have cannons and cannonballs as part of the story line, children's books on pirates provide a good connection to language arts. Neal's book *The Pirate Who Couldn't Say Arrr!* (2011) will appeal to younger learners; Carlson's book *The Very Nearly Honorable League of Pirates: Magic Marks the Spot* (2013) will appeal to students at the upper elementary levels. Students can write their own stories or poems, draw or paint pictures, perform skits, and make up songs or melodies to go along with this investigation. The Air Cannon investigation has the potential

FIGURE 2

Students return to the build stage (step 4; see the **sidebar** on **p. 504**) if they think they can improve on their design. This process continues until they create the best model possible that meets the conditions of shooting the cotton ball as far as possible.

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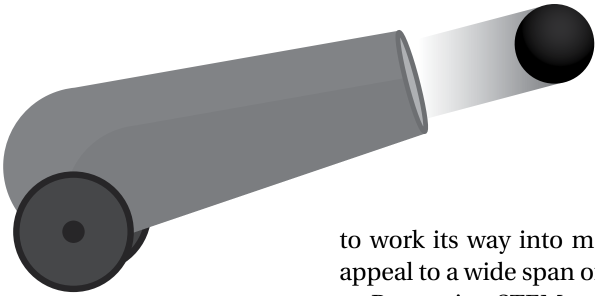

to work its way into many different topics and appeal to a wide span of student interest.

Presenting STEM activities in the classroom is one way of engaging students in worthwhile mathematical investigations. Such involvement allows students to see how various content areas relate to and support each other in real problems. Preparing them to tackle these problems is what teachers strive to achieve. We also cannot overlook the fact that students will get excited when they hear the teacher say, "Ready, aim, fire your cannons!"

FIGURE 3

Students may use this activity sheet to navigate through the Air Cannon investigation. A full-size version is available; to access it, see the **more4u** box at the end of this article.

iSTEM activity sheet

Date ______________________________ Name______________________________

Air Cannon Investigation: Ready, Aim, Fire!

Materials you will need		
• A cup or container	• Cotton balls or puff balls	• Duct tape or packing tape
• A plastic bag	• Scissors	• A tape measure

Today you will create your own version of a cannon that can shoot a cannonball.

Throughout the process, we will be using STEM concepts to help us create cannons, investigate how they can shoot a cotton ball, and collect data from these instruments to make sense of important principles we are studying.

1. Think about how to build your own air cannon using the identified materials. Your goal is to have the cannon shoot a cotton ball as far as possible.
2. Sketch and jot notes about this process in your engineering design journals. You are to record one or two prototypes of your air cannon.
3. Collect materials provided in the classroom for building it.
4. Build the air cannon. Don't forget to cut a hole in the cup or container for the cotton ball. Predict how far it will shoot it out.
5. Test it. How does your prediction match the actual launch of the cotton ball? You may wish to test several variables before proceeding. For example, try a different method for "loading" the air cannon with air, or experiment with different techniques of applying force to "shoot" the cannon.
6. Once you have determined the best method for shooting your air cannon, use what you have learned to respond to the following:
   a. How does the force of pushing the bag impact the cotton ball?
   b. Does the size of the bag matter when you fire the cotton ball? In other words, will the cotton ball go farther with a bigger bag? How do you know?
   c. Does the size of the cup or container make a difference in how far the cotton ball goes?
   d. Shoot your air cannon at least ten times and take measurements (using the tape measures) of how far the cotton ball goes. Record these data in a chart. Using these data, find the mean, median, and mode.
7. Think about whether the results would be different with a different air cannon. Record your thoughts/responses.
8. Now connect with another classmate. Look at his or her air cannon and data that were generated. How are the results similar to yours? How are they different?
9. With your partner, create a new air cannon. Shoot it ten times per person (for a total of twenty times) and take measurements of how far the cotton ball travels for each shot. How are the data the same? Different?
10. Based on your air cannons, make some conclusions about the "best" cannon and reasons it is the best. Be sure to use data to support your results.

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