ENGINEERING SELTZER ROCKETS

by Kevin Cunningham

Building and launching model rockets is an intrinsically interesting and exciting way for students to learn in the contexts of science, technology, engineering, and mathematics (STEM). Ever since *Sputnik* first turned the attention of a generation toward the exploration of space over half a century ago, thousands of elementary, middle, and secondary instructors have incorporated various aspects of rocketry into their curricula (Napier 2015).

Unfortunately, purchasing a commercial model rocket for every student is beyond the means of many classrooms. Furthermore, such rockets are propelled by dangerous combustions, and their performance is sensitive to even small changes in design, materials, and construction. This limits their pedagogical value, because students cannot safely or easily plan, construct, and evaluate their own vehicles and engines. These problems can be avoided, however, with more tranquil chemistry.

This article describes an activity in which students test and refine seltzer rockets—film canisters powered by effervescent tablets. This simple and low-cost method allows students to explore and improve the propulsion of legitimate rockets. In doing so, students also develop core understandings and practices in science and engineering identified by the *Next Generation Science Standards* (*NGSS*).

Materials, performance, and science of the seltzer rocket

To launch a seltzer rocket, at least one-quarter of an effervescent tablet and just enough water to cover it are placed in a 35 mm film canister. A tight-fitting lid is quickly secured and the canister is turned over so the lid serves as the rocket's base. The water dissolves the tablet**,** allowing sodium bicarbonate and citric acid in the tablet to react, generating gaseous carbon dioxide. As more CO_2 is produced, the pressure it creates within the canister builds until the lid can no longer contain it. This process can happen almost instantaneously or over a minute or more, depending on several factors (e.g., the temperature of the water).

When the gas finally pushes the lid out of the way, it also propels the canister upward, obeying Newton's third law and acting just like a rocket using a combustible fuel. However, unlike traditional rockets, seltzer rockets can be safely launched indoors. More importantly, because its performance is influenced by several easily observed and manipulated variables, the seltzer rocket is an excellent vehicle for developing students' understanding of motion, forces, and energy, as well as investigational and engineering skills.

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Engaging students in engineering seltzer rockets

There are many strategies for engaging students in the designing, building, and launching of rockets. One way to do this is to show them short videos of rockets being launched, including those used to lift people, equipment, and supplies into orbit, as well as much smaller models of real and imagined rockets built and launched by rocketry enthusiasts (brief descriptions of suitable videos can be found in the online supplements at *www.nsta.org/middleschool/connections.aspx*). In addition to a great "hook" and introduction to the activities that will follow, this provides an opportunity for teachers to strengthen students' understandings of *models*, particularly how model rockets differ from the devices they are sometimes used to represent.

It is important to introduce the concept of *engineering* at this point, because that process is integral to this activity. Begin by sharing some illustrations and photos of famous rockets and how they have changed over time (see the online supplementary materials for a guide). To stimulate students' thinking and conversations, ask them to write answers to these questions:

- How have rockets changed over time?
- Why do you think rockets have changed over time?
- What do we call the people who have worked to change rockets over time?

Once they have completed their answers, ask students to share their responses with those nearby. In addition to providing opportunities for students to learn from one another, this gives the instructor a chance to gather information about students' prior knowledge and experiences.

Students are likely to have many ideas about how and why rockets have changed, but the key is realizing that people have intentionally changed rockets over time so those devices can perform existing tasks better or perform new tasks. We call people who work to improve rockets (and every other tool humans rely on) *engineers*, and we call the process used to make those improvements *engineering*.

After this brief introduction, students are ready to begin some basic engineering by working to launch their own rockets. Although the instructor provides some guidance, this part of the activity is kept intentionally open to allow students to become familiar with the behavior of seltzer rockets primarily through independent, trial-and-error explorations.

Students are presented with the following task: Working as engineers in groups of two or three, develop a procedure for launching a 35 mm film canister using effervescent tablets (e.g., Alka-Seltzer). In doing so, each team must follow these requirements (see the activity worksheet provided below):

1. Safety goggles must be worn *at all times*.
2. Your instructor will provide you with two effervescent tablets, *but you cannot use them until you have been told to do so*.
3. Rockets must be launched from within a launch pad (a large, low-sided, plastic storage container) placed on the floor (see Figure 1), and a successful launch is one in which the film canister (not the lid) hits the ceiling.
4. Do not launch a rocket beneath anything on the ceiling that may be damaged, and never stand over a rocket while waiting for it to launch.
5. Because the results of scientific investigations and engineering design must be *reproducible*, each team must perform *three* successful launches.

Before doing this with students, instructors should try launching seltzer rockets for themselves. If launched outside or in a room with a very tall ceiling (like a gymnasium), 35 mm film canisters can reach heights of over six m (20 ft). Because effectively launched canisters can strike lower ceilings with considerable force, seltzer rockets should not be launched beneath exposed light bulbs or other, easily damaged objects. Students must also wear safety goggles whenever anyone in the room is launching seltzer rockets, and they should be warned not to stand over film canisters that may launch unexpectedly.

FIGURE 1 Preparing to launch a seltzer rocket from a launch pad

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Engineering teams can be assigned by the instructor or selected by students. Each team needs safety goggles, a launch pad, and a film canister and lid. It is best for students to choose their 35 mm canisters and lids from among several similar but slightly different types, because determining what kind of canister and lid work best is an important goal of this initial exploration (various types of canisters/lids and how they can be obtained are described in the online supplement).

Although they are not explicitly told so, most students will quickly recognize that water is needed to activate the seltzer tablets (and those who do not realize this will once they see others using water). Therefore, if there is no source for water in the room, a large container of tap water (a gallon jug will do) and smaller, plastic containers to hold a small amount of water for each group must be set out for students to access. Because the seltzer rockets are launched from within low-standing, plastic containers (the "launch pads") that will hold any spilled water, there is little need to worry about messes. Nevertheless, it is nice to provide students with small towels to wipe their hands (two large, old bath towels can be torn into enough pieces to give 10 groups one hand towel apiece).

When everyone has gathered whatever materials they feel are needed and dispersed themselves around the room, teams should be given a short time to plan how they will launch their rockets (two minutes are generally sufficient). As plans are being discussed, the instructor checks that all students have their safety goggles in place and all launch pads are placed on the floor (so each team launches from the same height). The instructor also gives each team one packet containing two effervescent tablets (use generic tablets to save money) and reminds students that they cannot open their packets until they have been told to do so (this ensures that all teams start working to launch their rockets at the same time).

Starting each team with only two effervescent tablets should help at least some students to realize that they must use less than a whole tablet for each launch if they are going to make three successful launches. Some students may also find that if a whole tablet is used for a launch, what remains of the tablet after the launch can generally be used again to power at least one more successful launch. It is rare for at least one group to not have launched a film canister within several minutes, although it may take several tries for each group to get a canister to hit the ceiling. Teams that use up both tablets before producing three successful launches can be given additional tablets as needed.

After a team has performed three successful launches, the instructor should ask its members to help those still lacking a successful launch. Student coaches should be told to *guide* their classmates in solving their problems and not to simply do it for them. Instructors can also assist by directing students to look carefully at what the canisters that have failed to launch are doing and to think how that might explain why the canisters are not launching. The problem can almost always be traced to a lid that allows gas to slowly escape because it does not make a tight seal with its container (see Figure 2). It is important to allow enough time for every team to perform at least one successful launch so every student has witnessed that process firsthand and ended this part of the activity with a sense of accomplishment.

Before moving on to the next stage of the seltzer rocket activity, students should summarize what they have learned up to this point by answering and then discussing their responses to questions such as:

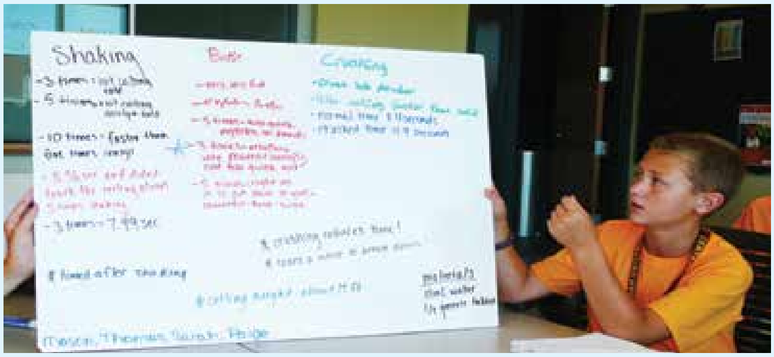
- What was one problem you had to solve to get your seltzer rocket to launch successfully? How did you solve that problem?
- What factors are most likely to influence the performance of the seltzer rocket? How will each factor affect the performance? Why do you think it will have that effect?
- Write a simple set of directions that other students could easily follow to successfully launch a seltzer rocket.
- How did you act like an engineer in working to successfully launch your seltzer rocket?

These and additional questions are provided as part of the activity worksheet provided below.

Once students have used some simple, trial-and-error engineering to familiarize themselves with the basic operation of the seltzer rocket, the device can serve as a vehicle for helping them to refine those practices, as well as to understand some important, scientific concepts. This will require students to (1) systematically investigate those factors that can influence the behavior of the seltzer rocket and (2) explain the behavior of the seltzer rocket by applying some basic principles of physical science.

FIGURE 2 A poorly fitting lid prevents a seltzer rocket from launching

FIGURE 3 Presenting seltzer rocket data



Investigating seltzer rockets to strengthen science and engineering practices and physical science concepts

In the second major stage of the seltzer rocket activity, students systematically investigate those factors that can influence the behavior of the seltzer rocket to identify the best conditions for a successful launch. They will also apply scientific principles with what they have learned to explain the behavior of the seltzer rocket.

To legitimize and incentivize their work, students' investigations can be framed in the following context:

> The owners of a large business are interested in manufacturing and marketing the seltzer rocket as a toy to be sold to schools, parents, and children. Before the owners will invest in this product, however, they must be convinced that the behavior of the seltzer rocket is well understood. In particular, they require specific directions describing the best conditions for successfully launching a seltzer rocket. Working as a collaborative group of engineers, your class must produce those instructions and explain how the seltzer rocket works.

To complete this task, students must identify those factors that are most likely to influence the behavior of the seltzer rocket, determine how those factors can be used to maximize the performance of the seltzer rocket, effectively communicate that information to the potential investors, and then simplify those results to produce a concise set of instructions for operating the seltzer rocket that even young children can easily understand. Students began this process in the previous stage of the seltzer rocket activity. However, to generate convincing data regarding the best conditions for launching seltzer rockets, students must now develop and conduct more systematic, controlled, experimental procedures.

Unless they are very familiar with planning and carrying out fair tests that change only one variable at a time while keeping all others constant, it is likely that students will need some guidance in testing the performance of their seltzer rockets. Students may also require assistance in determining which factors to test. Aside from having a film canister with a tight-fitting lid, these include the amount of effervescent tablet and water, the type of effervescent tablet (generic versus name brand), the temperature of the water, and the effect of crushing the effervescent tablet and shaking the film canister after the effervescent tablet and water have been sealed inside. Students may also need some support in how to best communicate this information to classmates, their instructor, and potential investors (Figure 3).

The *NGSS* make it clear that science and engineering practices should not be developed in isolation; rather, content should be learned in conjunction with relevant scientific concepts (NGSS Lead States 2013, p. xiii). To support students' understandings of basic scientific principles involving motion, forces, and energy, they can use their seltzer rocket investigations to address two middle school *NGSS* performance expectations (PEs):

Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013)

- The chart below makes one set of connections between the instruction outlined in this article and the *NGSS*. Other valid connections are likely; however, space restrictions prevent us from listing all possibilities.
- The materials, lessons, and activities outlined in the article are just one step toward reaching the performance expectations listed below.

Standards

MS-PS3: Energy (*www.nextgenscience.org/dci-arrangement/ms-ps3-energy*)

MS-ETS1: Engineering Design (*www.nextgenscience.org/dci-arrangement/ms-ets1-engineering-design*)

Performance Expectations

MS-PS3-5. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Dimension	**Name and *NGSS* code/citation**	**Matching student task or question taken directly from the activity**
Science and Engineering Practice	Analyzing and Interpreting Data	Students will analyze the data they gather through their investigations of the seltzer rocket to determine its best operating conditions.
Disciplinary Core Ideas	PS3.B: Conservation of Energy and Energy Transfer • When the kinetic energy of an object changes, there is inevitably some other change in energy at the same time.	How does the energy of the seltzer rocket change when it is launched into the air? How do you know the seltzer rocket has energy, and where did that energy come from?
	ETS1.B: Developing Possible Solutions • A solution needs to be tested and then modified on the basis of test results, in order to improve it.	If your rocket fails to launch successfully, think about things you can change that might affect the rocket's performance, and then do more tests.
Crosscutting Concept	Cause and Effect	Describe the mechanism that launches the seltzer rocket into the air, and identify the central cause-and-effect relationship involved.

Connections to the *Common Core State Standards* (NGAC and CCSSO 2010)

www.corestandards.org/ELA-Literacy

CCSS.ELA-LITERACY.WHST.6-8.1.B: Support claim(s) with logical reasoning and relevant, accurate data and evidence that demonstrate an understanding of the topic or text, using credible sources.

- MS-PS3-5. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.
- MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

The first PE requires students to apply their understanding of kinetic energy to the launch of the seltzer rocket. The second PE requires additional investigation in which increasing mass is added to a film canister for which all other variables affecting its launch are kept constant (and those variables should have the values determined to produce the best launches in earlier experiments). One way in which the mass of the seltzer rocket can be easily increased incrementally is to tape washers to it. They should be the smallest available, however, because even small washers will increase the mass of a 35 mm film canister by a significant percentage.

Here are some questions involving both PEs that students should be expected to answer:

- Describe the mechanism that launches the seltzer rocket into the air, and identify the central cause-and-effect relationship involved.
- How does the energy of the seltzer rocket change when it is launched into the air? How do you know the seltzer rocket has energy, and where did that energy come from?
- Draw two simple models that identify all of the forces acting on the seltzer rocket just before and just after it is launched into the air. Use your models to explain why the film canister moves upward when it is launched.
- How does the seltzer rocket's upward motion change as the mass of the canister increases? Why does this happen?

Additional questions and other details for how these PEs can be addressed are provided in the activity worksheets accompanying this article.

Conclusion

Investigating and engineering seltzer rockets uses students' intrinsic interest in and excitement with things that explode, go fast, and fly through the air. It does so, however, in a safe and convenient way while developing important skills and understandings of the *NGSS*. Perhaps a simple seltzer rocket will also fire the imagination of a future aerospace engineer or inspire a child to become one of the first astronauts to stand on Mars.

More details and possible extensions

Additional details and potential extensions are provided in a supplementary document available online (*www.nsta.org/middleschool/connections.aspx*). ■

References

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Student task sheet #1: Developing a procedure for launching a 35 mm film canister using effervescent tablets.

In this engagement part of the seltzer rocket activity, students begin some basic engineering by working to launch their own seltzer rockets. Although the instructor provides some guidance, this is kept intentionally open to allow students to become familiar with the behavior of seltzer rockets primarily through independent, trial-and-error exploration. Everything below can be easily copied and pasted into a separate document, edited by instructors to suit their classrooms, and then printed and given to students.

Title: Launching seltzer rockets.

Purpose: To learn about engineering and the operation of seltzer rockets.

Objective: To develop a procedure that can be used to successfully and consistently launch a 35 mm film canister using effervescent tablets (Alka-Seltzer tablets or their generic equivalents).

Required materials (available at the teacher's desk):

- safety goggles (to be worn **at all times**)
- 35 mm film canister and lid
- plastic storage container (this will serve as your launch pad)
- effervescent tablets (these will be given to you by your instructor once you have all of your other materials and everyone on your team is wearing safety goggles)

Optional materials (available at the table in the back of the room):

- water and a small container to hold in the water
- hand towels (to wipe your hands or clean up any small spills)

Procedures:

1. Safety goggles must be worn ***at all times***.
2. Your instructor will provide you with two effervescent tablets, *but you cannot use them until you have been told to do so*.
3. All rockets must be launched from within a launch pad (a plastic storage container) that is sitting on the floor, and a successful launch is one in which the film canister (not the lid) hits the ceiling.
4. Do not launch a rocket beneath anything that may be damaged on the ceiling, and never stand over a rocket while waiting for it to launch.
5. Because the results of scientific investigations and engineering design must be *reproducible*, each team must perform *three* successful launches.

Additional guidelines: These suggestions may help your team successfully launch its seltzer rocket.

1. Look carefully at what the canister and its contents are doing while waiting for it to launch. If your rocket fails to launch successfully, try to determine why that happened by thinking about what you saw and discussing it with the other engineers on your team.
2. If your rocket fails to launch successfully, think about the things you can change that might affect the rocket's performance, and then do some tests to determine if any of those changes produce a successful launch.
3. If your rocket fails to launch successfully, talk to the engineers on other teams about ideas you might use to produce a successful launch.
4. Once your team has performed <u>three</u> successful launches, help other teams to launch their rockets successfully. Do <u>not</u> simply launch their rocket for them. Instead, help them to understand what is happening by asking them questions or pointing out things they should be looking at or thinking about.

Conclusion: Summarize what you have learned about the seltzer rocket and engineering by writing complete answers to these questions. You will be asked to share your responses with the rest of the class.

1. What was one problem you had to solve to get your seltzer rocket to launch successfully? How did you solve that problem?
2. What factors are most likely to influence the performance of the seltzer rocket?
3. Write a set of directions that other students could easily follow to successfully launch a seltzer rocket. Your directions must be written in short, numbered steps using clear and simple wording.
4. How did you act like an engineer when you worked to successfully launch your seltzer rocket?
5. If what you did to successfully launch your seltzer rocket is an example of *engineering*, how would you define that word so other students can easily understand its meaning?

Student task sheet #2: Investigating seltzer rockets to strengthen science and engineering practices and understandings of motion, forces, and energy

In this second major stage of the seltzer rocket activity, students systematically investigate those factors that can influence the behavior of the seltzer rocket to identify the best conditions for a successful launch. They will also apply scientific principles along with what they have learned to explain the behavior of the seltzer rocket. Everything below can be easily copied and pasted into a separate document, edited by instructors to suit their classrooms, and then printed and given to students.

Title: Investigating and explaining the behavior of the seltzer rocket.

Purpose:

1. To practice planning, conducting, and communicating the results of controlled, experimental procedures.
2. To strengthen understandings of physical science principles involving motion, forces, and energy.

Objectives:

1. To identify the factors most likely to influence the behavior of the seltzer rocket and to perform fair tests to determine how those factors can be used to maximize the performance of the seltzer rocket.
2. To effectively communicate the results of testing the seltzer rocket and to then simplify those results to produce a concise and clear set of instructions for operating the seltzer rocket.
3. To explain the behavior of the seltzer rocket by applying concepts of motion, forces, and energy.

Materials:

- safety goggles (to be worn whenever rockets are being launched in the room)
- 35 mm film canister with a tight-fitting lid
- plastic storage container (your launch pad)
- effervescent tablets (generic, although some groups will use name brand tablets)
- room temperature, warm, and cold water
- graduated cylinder to measure volumes from 1–25 mL
- hand towels (to wipe hands or clean up any small spills)

Introduction: The owners of a large business are interested in manufacturing and marketing the seltzer rocket as a toy to be sold to schools, parents, and children. Before the owners will invest in this product, however, they must be convinced that the behavior of the seltzer rocket is well understood. In particular, they require specific but concise instructions describing the best conditions for successfully launching a seltzer rocket. Because the seltzer rockets may be operated by young children, the instructions must be short and written using clear and simple wording.

In the previous activity, you learned some of the basic requirements for successfully launching a seltzer rocket and wrote some general instructions for doing so. In this activity, you and the other engineers in your class will improve those instructions by planning and conducting additional investigations to determine the best operating conditions for launching the seltzer rocket. Because they may be operated by young children, it is important that the seltzer rockets do not launch too quickly (less than 5 seconds) or too slowly (more than 15 seconds) after the effervescent tablet has been added to water and the canister is sealed.

Before they commit resources to manufacturing and marketing the seltzer rocket, the business owners also expect the behavior of the seltzer rocket to be well understood. You and your team of engineers must therefore also explain how and why the seltzer rocket behaves as it does by applying some basic principles of motion, forces, and energy.

Procedures:

1. Your instructor will assign your group of engineers one of the following factors to test:
    - The amount of effervescent tablet
    - The amount of water
    - Generic versus name-brand effervescent tablets.
    - The effects of crushing the tablet and shaking it with water before the canister is set down to launch
    - The temperature of the water
2. You and your engineering partners must plan a fair test (sometimes known as a *controlled experiment*) to determine the best conditions for operating seltzer rockets with respect to the factor you have been assigned. For example, if you have been assigned to test the amount of effervescent tablet, you must plan for how you will decide what is the best amount of effervescent tablet to use for each launch.

Student task sheet #2 (continued)

Your plan must be clearly described in the planning sheet for testing the selzer rocket (provided below) and approved by your instructor before you begin your testing. To help you plan a fair test that will produce good results, follow these guidelines:

- To ensure that everyone's results will be comparable, these are the conditions that everyone will use when launching their rockets—a 35 mm canister with a tight-fitting lid containing 10 mL of room temperature water and 1/2 of a fresh, generic effervescent tablet that has not been crushed or shaken after adding it to the water in the canister.
- To ensure that your tests are fair, only the factor that you are testing can be changed; every other aspect of the seltzer rocket described in the paragraph above must remain constant. For example, if you have been assigned to test the amount of effervescent tablet, you can only vary the amount of effervescent tablet you use for each launch; everything else should be as described in the paragraph above.
- You must plan what data you will record during your tests and design an appropriate table for recording that information. To ensure that your data are reliable, you must conduct multiple tests (at least three) for each different value of the factor you are testing. Whenever possible, make accurate measurements using whatever tools may be available.

3. Safety goggles must be worn whenever anyone in the room is launching seltzer rockets. All rockets must be launched from within a launch pad (a plastic storage container) that is sitting on the floor, and a successful launch is one in which the film canister hits the ceiling. Do not launch a rocket beneath anything on the ceiling that may be damaged, and never stand over a rocket while waiting for it to launch.

4. When you have completed testing your factor, check your results with your instructor. Once your results have been approved, gather more evidence to answer the questions below. This may require you to perform additional investigations. Your instructor will provide you with materials if you need them.
   a. Describe the mechanism that launches the seltzer rocket into the air, and identify the central cause-and-effect relationship involved.
   b. How does the energy of the seltzer rocket change when it is launched into the air? How do you know the seltzer rocket has energy, and where did that energy come from?
   c. Draw two simple models that identify all of the forces acting on the seltzer rocket just before and just after it is launched into the air. Use your models to explain why the film canister moves upward when it is launched.
   d. How does the seltzer rocket's upward motion change as the mass of the canister increases? Why does this happen?

5. Develop a presentation of your work that consists of two parts:
   - Part 1: information regarding the factor you tested and how the seltzer rocket works best (Steps 1 and 2 of the procedure above). This should include the factor that you tested, how you varied that factor, how your tests were controlled, the data you collected, your recommendation for the best condition for operating seltzer rockets with respect to the factor you tested, and how that recommendation should be phrased as concisely as possible in a way that even young children can easily understand.
   - Part 2: information regarding why the seltzer rocket works the way it does. This should include responses to all of the questions in Step 4 of the procedure (above).

   Your instructor will provide you with the materials needed to construct your presentation.

Planning sheet for testing the seltzer rocket: Your group must complete everything below and have it approved by your instructor before you can begin testing the seltzer rocket.

1. Names of the engineers in your group
2. What factor affecting the performance of the seltzer rocket will you be testing?
3. Predict how changing this factor will affect the performance of the seltzer rocket. Why will changing this factor have the effect you predicted?
4. How will you vary the factor you are testing?
5. How will you keep all other factors that might affect the performance of the seltzer rocket the same?

Student task sheet #2 (continued)

6. What data will you record as you test your factor? Draw a well-organized table below in which you can record your data. Remember that, to ensure your data are reliable, you must conduct multiple tests (at least three) for each different value of the factor you are testing.

Conclusion: Summarize what you have learned about the seltzer rocket, specifically planning and conducting controlled, experimental procedures, and effectively communicate their results by writing complete answers to the following questions:

1. What factor affecting the performance of the seltzer rocket did you test, and how did you vary it?
2. How did varying this factor affect the performance of the seltzer rocket?
3. How did the results of your experiment compare with the prediction you made in your planning sheet? If they were different, why do you think they were different?
4. What is your group's recommendation for the best condition for operating seltzer rockets with respect to the factor you tested? Write your recommendation as concisely as possible in a way that even young children can easily understand.
5. Of all the factors that were tested by the engineers in your class, which had the greatest effect on the performance of the seltzer rocket? What evidence do you have to support your answer?

Additional guidelines for instructors:

- Rather than simply assigning factors to test, instructors may wish to have students determine which factors should be tested based on their work in the previous activity and some additional brainstorming efforts. Before they begin their testing, it is also valuable for students to discuss and collaboratively develop specific criteria for their investigations (e.g., are multiple trials necessary? Why? What is the minimum number of trials needed?) and the criteria for operating the seltzer rocket (e.g., what should be the minimum and maximum times between when the contents are added to the film canister and the launch of the rocket?).
- While not necessary, it is helpful to have stopwatches or other easily operated devices (e.g., cell phones) that students can use to measure how long it takes for the seltzer rockets to launch after they have been sealed and placed on the launch pad. If watches are not available, students can approximate the time by counting "one-thousand-one, one-thousand-two…" If thermometers and balances are available, instructors may also want to have students use them to measure water temperatures and amounts of seltzer tablets (but again, this is not necessary to produce good results; students can estimate fractions of tablets and describe water as cold, cool, room temperature, warm, and hot).
- Students in a given class need not test all of the factors listed above. It is best to have more than one group test any given factor so comparisons between their results can be made.
- As students are testing their rockets, the instructor should check to see that each group is recording its data. It is sometimes easy for students to become so engaged in testing that they neglect to do this.
- Effervescent tablets can be easily crushed by stepping on the packet they came in before opening it or by putting tablets in a plastic bag and stepping on it.
- Group presentations can be done on large sheets of paper; on large, individual whiteboards; or electronically. The recommendations of all the groups in a class can be combined to produce a single set of instructions for operating the seltzer rocket.
- Responses to the questions in Part 2 of students' presentations should be used as points for further discussion as well as opportunities to learn from one another and the instructor.
- Some of the concluding questions may seem repetitive, as they address issues that were to be part of students' class presentations. However, asking each student to answer those questions independently at the end of the activity provides evidence that individuals understand what was done and why.