# OUT-OF-SCHOOL TIME TOP TEN

## ACTIVITY BUNDLE

**For All Grade Levels**

Career-connected learning helps youth understand the world of work, build critical life skills, and imagine themselves in a range of future possibilities.

The ten activities included are what STEM Next has seen throughout afterschool programs as some of the most common STEM activities that programs use. This activity bundle expands upon them and builds in career-connected learning, introducing young people to the careers associated with each activity.

# STEM Next Out-of-School Time Top Ten Activity Bundle

**Welcome to the STEM Next Top Ten Activity Bundle!**

The ten activities below are what STEM Next has seen throughout afterschool programs as some of the most common STEM activities that programs use. This activity bundle expands upon them and builds in career-connected learning, introducing young people to the careers associated with each activity.

Through these activities, youth develop foundational STEM skills by engaging in hands-on investigations while building career awareness by exploring how professionals use science, technology, engineering, and math.

Interested in more resources like this from STEM Next? Check out our Tools in our online Resource Library.

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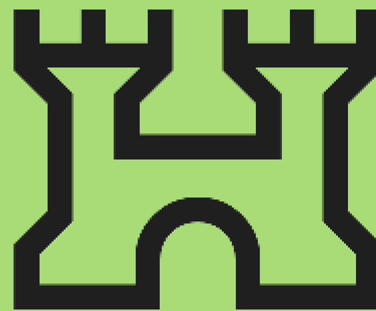
# Activity 1: Tower Challenge



**In this lesson, youth will be able to:**

- Use the engineering design process to complete a design challenge.
- Understand the difference and importance of constraints and criteria.
- Communicate and collaborate with peers to reach a goal.

**Age range:** Grades 3-8
**Time needed:** 50 minutes

## Preparation

| | |
|---|---|
| **Materials** | • Small stuffed animal prey<br>• Index cards (40 per small group)<br>• Masking tape (2 ft per small group)<br>• Ruler/meter stick/measuring tape |
| **Setup** | • Cut 2 ft of masking tape per small group<br>• Count out 40 index cards per small group |
| **Presentation** | Slides |

## Facilitation

**Overview:**

In this hands-on engineering challenge, teams plan, build, test, and iterate a paper tower to protect a rare wetland animal from a predator, working within material limits and time constraints to practice problem-solving, measurement, and collaboration. The activity emphasizes the engineering design process through ideation, testing, and redesign.

**Engage:**

1. Ask youth: *What does it mean if an animal is endangered?* Allow 2–3 youth to share their ideas. Then explain: *An endangered species is a plant or animal that is at risk of disappearing forever because there are very few left in the wild.*
2. Show a picture and read the name of an animal (Slide 2–6). Youth should give a thumbs up if they think it is endangered or a thumbs down if they think it is not endangered.

| **Animal** | **Endangered** | **Fun Fact** |
|---|---|---|
| Giant panda | No | Many think it is endangered but due to conservation efforts, its population is increasing. |
| Bald eagle | No | Once endangered in the US, it has recovered thanks to conservation and is now a success story. |
| Sea turtle | Yes | Many species of sea turtles are threatened by plastic pollution and fishing nets. |
| Orangatan | Yes | Rainforest habitat loss is one of the biggest threats to orangutans. |
| White-taile d deer | No | They are common across much of North America. |

**Investigate:**

1. Set the story behind the tower challenge (Slide 7): *An alligator (or other predator of your choice) is lurking in a wetland hunting a rare species that biologists want to protect. Your challenge is to build a platform that will support the prey (stuffed animal) so that it is not eaten!*

2. Depending on the previous experience of youth in your group, introduce or review the engineering design process (Slide 8). Explain: *The engineering design process is a problem-solving method. It can be used to solve big problems like building a space capsule or smaller problems like building a*

*paper tower. By following the steps, you will be able to complete almost any task.*

3. Ask youth: *What do you need to know to solve this engineering challenge?* Capture the questions youth ask on a list on a whiteboard or poster paper. Some possible questions might be:

    - How large is the species that we are saving?
    - How much does the rare species weigh?
    - What materials can we use?
    - How long do we have to make it?

    Go back to the beginning of their question list and answer each.

4. Reveal the materials: tape, index cards, tools. Explain: Criteria are things that must be included or that the tower must do. Constraints are the limits or things that can not be included or done to the tower (Slide 9). Reveal the criteria and constraints.

    **Criteria:**

    - Building materials are 40 index cards and 2 feet of tape. You may use fewer than 40 cards if you desire.
    - Cards can be taped, folded, and bent as desired. The cards cannot be cut.
    - The tower needs to be 10 inches high.
    - The tower must be free standing and cannot be taped to the table or floor.
    - The tower must support the prey for 10 seconds without falling.

    **Constraints:**

    - The ruler cannot be part of the design; it is a tool only.
    - You have 15 minutes to complete the task (more time may be allowed).
    - You cannot pre-test with the stuffed animal prey. Wait until everyone is ready to test.

5. Allow 5 minutes for youth to imagine solutions to the problem individually. Youth may pass around the stuffed animal to feel its weight. If desired,

pass around a few index cards that have been shaped in different ways that might inspire a design (triangle fold, column or cylinder shape, accordion fold).

6. Separate youth into groups of 3. Have youth share their individual ideas with their working groups. Then, ask each small group to agree on a plan. Allow groups 5 minutes to create and draw a diagram of their plan.
7. Let youth create their towers. Allow at least 15-20 minutes of build time. Do not test the towers with the stuffed animal prey yet.
8. When time is up, have each group measure their towers to see how close they came to the 10” tall criteria. Then have youth predict how well they think the tower will perform. Take turns testing each platform with the stuffed animal prey. Celebrate their efforts! As groups are testing, discuss what changes each group might make using the materials provided.
9. After all groups have tested, allow 5 minutes for groups to improve their tower and retest. Take turns testing each platform with the stuffed animal prey. Celebrate their efforts!

**Wrap-up:**

1. Ask youth: *How might you improve your designs? What did you notice about others' design efforts? How well did your group work together? What was the most difficult thing about working with a group? What was the best thing about working with a group?*
2. Show a diagram of the engineering design process. Ask youth: *Which of these steps did you use when creating the tower?* Have youth expand upon their answers.

## Implementation

**Alternative facilitation:**

- Revisit this activity again with different criteria and constraints, such as fewer cards, no tape, build to a greater height, longer time to remain standing, larger prey.

**Career Connection:**

- Zoologist and wildlife biologist
  - Share career profile.
  - Sophie Gilbert: Wildlife biologist | Science Trek
- Conservation scientist and forester

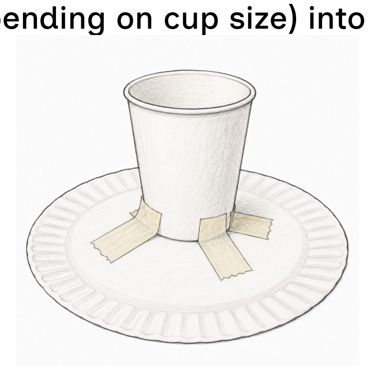
# Activity 2: Soft Landing

**In this lesson, youth will be able to:**

- Use the engineering design process to complete a design challenge.
- Understand the difference and importance of constraints and criteria.
- Communicate and collaborate with peers to reach a goal.

**Age range:** Grades 5-8
**Time needed:** 50 minutes

## Preparation

| | |
|---|---|
| **Materials** | • Small plastic or paper cup (1 per small group)<br>• Paper plate (1 per small group)<br>• Jumbo marshmallows (2 per small group)<br>• Miniature marshmallows (2 per small group)<br>• A variety of materials to be used to build the lander, such as cotton balls, index cards, plastic straws, tape, scissors, construction paper, rubber bands, craft sticks, pipe cleaners, string, plastic grocery bags |
| **Setup** | • Attach the plastic or paper cup to the paper plate using tape as shown below. Make one lander for each group of 2–3 youth. Place 2 marshmallow astronauts (big or small depending on cup size) into each lander.<br><br>• Gather all materials that youth can use to build the lander and place in a materials hub.<br>• Set up a testing station with a measuring tape so teams can measure their drop height. |

| Presentation | [Slides] |
|---|---|

## Facilitation

**Overview:**

This engineering design challenge introduces youth to the problem-solving practices used by real aerospace engineers as they design, build, test, and improve a model moon lander for the Artemis II mission. Working in teams, youth use the engineering design process to create a lander that protects marshmallow astronauts while meeting specific design criteria and constraints.

**Engage:**

Watch the video (Slide 2) Artemis II Moon Mission Complete. Ask youth: *What was exciting in that video? Do you know what the next steps are for Artemis? Would you go to the moon?*

**Investigate:**

1. Share the story and challenge (Slide 3). Explain: T*wo astronauts are going to land on the far side of the moon. You are part of the design team that will create the moon lander. The lander must not disturb the soft, powdery surface of the moon and must keep the astronauts in an upright and safe position.*
2. Show the lander (cup attached to the plate) to youth. Place 2 marshmallows (large or small depending on the size of the cup) into the cup to represent the astronauts. Demonstrate dropping the lander from 3 feet (waist high). Ask youth: *What kinds of problems do you see with this basic lander? What kinds of things do you need to consider to make the lander safer for the astronauts?*
3. Depending on the previous experience of the youth, introduce or review the engineering design process (Slide 4). Explain: *The engineering design process is a problem-solving method. It can be used to solve big problems like building a space capsule or smaller problems like building a moon lander model. By following the steps, you will be able to complete almost any task.*
4. Explain: *Criteria are things that must be included or that the lander must do. Constraints are the limits or things that cannot be included or done to the lander* (Slide 5). Reveal the criteria and constraints.

**Criteria:**

- All building must take place under the lander's platform.
- Astronauts must remain inside the lander at all times, even after landing.
- The lander must land softly from at least 3 feet above the surface. A height above 3 feet is preferred.

**Constraints:**

- No covering the cup or platform with any material.
- Do not change the cup, platform, or astronauts.
- Use only the materials provided.

5. Show youth the materials available to them and answer any questions. Allow 5 minutes for youth to individually draw their idea for the lander.
6. Place youth into groups of 2–3. Have youth share their individual ideas with their group members and decide upon a design for their group lander. Allow 5–10 minutes for this step. Have each group draw a diagram of their lander and list all the materials they will use.
7. Allow groups time to build. To limit congestion around the materials hub, have only one person from each group gather their materials. During the build time, groups should also test and iterate their design. Allow 15–20 for this step.

**Wrap-up:**

1. Ask each group to complete a final test of their lander in front of the whole group. Each group should explain their design, receive 2 new marshmallows, and demonstrate how their lander works. Give each group two trials to be successful.
2. After all groups have tested, ask: *What design options worked best? What would you change about your design?*
3. If time allows, have groups make modifications to their design. Have the groups retest to demonstrate the improvements.

## Implementation

**Career Connection:**

- Aerospace engineer
    - Share career profile.
    - PBS Learning Media-Challenge of Flight: Helps youth discover the science and engineering principles behind flight by exploring how aerospace engineers tackle real-world challenges in designing and testing aircrafts.
- Satellite technologist
    - Share career profile.

# Activity 3: Design a City Street

**In this lesson, youth will be able to:**

- Explain the importance of planning, the needs of citizens, and scale in city design.
- Apply math concepts of area, perimeter, and volume in a real-world context.
- Collaborate effectively to solve a design challenge.

**Age range:** Grades 6-12
**Time needed:** 60-80 minutes (*This activity may be broken into two sections if desired.*

| Preparation | |
|---|---|
| **Materials** | • Tape<br>• Brown poster/packing paper<br>• Scissors<br>• Markers/crayons<br>• Grid paper<br>• Measuring tape or ruler<br>• Calculator |
| **Setup** | • Determine the size of the space that will be used for your town. It is recommended to use a table covered with brown paper.<br>• To make facilitation easier, have the streets of the town already drawn on the paper in a grid-like fashion. |

## Facilitation

**Overview:**

In this activity, youth act as city planners to design and build a 3D model of an ideal community while working together to create a functional city layout. As they construct scale models of buildings, youth apply measurement and geometry concepts by calculating perimeter, area, and volume while exploring how cities are designed to meet community needs.

**Engage:**

Ask youth: *If you were designing a neighborhood, what would be some necessary things to include?* Write a list of essential items on a whiteboard or poster paper.

**Investigate:**

1. Explain that today youth are going to be city planners. They will make a 3D model of their perfect city. Youth will need to work together to ensure that all the necessary buildings and other needs are included in their model. Remind youth not to forget sidewalks, streets, parks, schools, etc.

2. If you have not pre-drawn the city streets, have youth determine the number of streets based on the list of essentials and draw them in the city. Draw the streets and sidewalks in the city space on the brown paper.

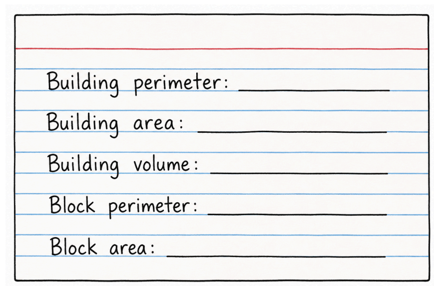
3. Have youth decide where each essential item should go in the city. Draw a box and label the location on the city layout. Allow for some extra spaces for non-essential places.

4. Separate youth into groups of 2–3. Assign each group a block in the city. Groups are responsible for building the 3D models of the structures in their block. Using grid paper, have youth begin building structures assigned to their block. Models should be built to scale so larger buildings are represented by larger models. (For example, a school should be larger than a house.) Once the buildings are made, have youth decorate them.

5. Have youth place their buildings in the correct place within the city. If some buildings are not to scale, have groups remake them.

**Wrap-up:**

- Once all the buildings are in place, have youth determine the size of their city. Have each group determine the perimeter, area, and volume of each building/structure they created. Have groups write this information on an index card at the end of the block they created. Depending on the number of buildings on the block, you may need to add room for additional individual building perimeter, area, and volume.



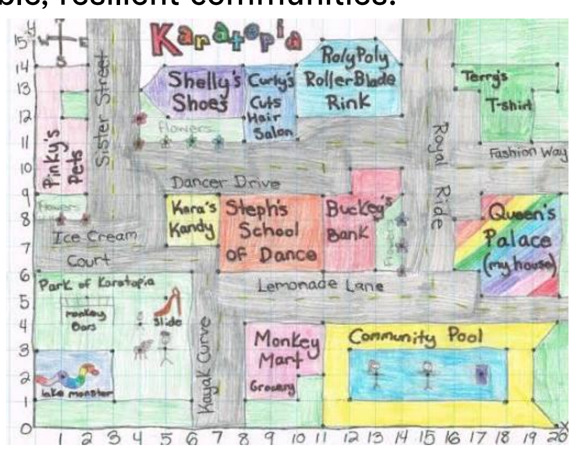

- As a group, calculate the total perimeter, area, and volume that the city covers.

## Implementation

**Alternative Implementation and Extension:**

- If space is limited and youth are unable to create a 3D model, have youth create their own cities on a piece of grid paper. Ask youth to draw and label the buildings and then measure and record the perimeter, area, and volume of each building and the entire city.

- Participate in the [Future City Competition](). The Future City Competition is a hands-on engineering program where middle school youth work in teams to design and build innovative cities of the future. Youth use science, technology, engineering, and math skills to solve real-world problems and create sustainable, resilient communities.



**Career Connection:**

- Urban planner
    - Share career profile.
    - MyTopia Green City Builder: An interactive game where youth make decisions about a simulated city and observe the environmental results.
- Surveyor
- Exploration geologist: Surprisingly STEM

# Activity 4: Don't Let it Pop!

**In this lesson, youth will be able to:**

- Identify indicators of a chemical reaction.
- Design and follow an experimental procedure to determine a conclusion.
- Use computational thinking and data to explain how reactant amounts influence chemical outcomes.

**Age range:** Grades 5-8
**Time needed:** 50 minutes

## Preparation

| | |
|---|---|
| **Materials** | • Sodium bicarbonate (baking soda)<br>• Acetic acid (vinegar)<br>• Zip-top sandwich bags (5 per small group)<br>• Measuring spoons (1 set per small group)<br>• Measuring cups/graduated cylinder (1 per small group)<br>• Small plastic or paper cups<br>• Don't Let it Pop document |
| **Set Up** | • Copy the Don't Let It Pop document.<br>• Fill a paper cup with baking soda. (1 per small group)*<br>• Fill a paper cup with vinegar. (1 per small group)*<br><br>**The cups may need to be refilled several times during the activity depending on their size.* |

## Facilitation

**Overview:**

This hands-on chemistry activity introduces youth to chemical reactions. Youth observe the signs of a chemical reaction and explore how changing the amounts of reactants affects the outcome of the reaction. Working in teams, youth apply problem-solving and experimental design skills to determine the correct ratio of reactants needed to fully inflate a plastic bag without causing it to burst.

**Engage:**

1. Place a large plastic/paper cup on a tray. Add several spoons of baking soda. Tell youth that you are going to add some vinegar, which is an acid, and they should make some observations about what they see. As you add the vinegar, the mixture will begin to bubble and foam. You should hear a sizzling sound and the bubbles may overflow the cup. The more dramatic the better. Ask: *What are you observing?* Youth may suggest bubbles and foam. Explain: *This was a chemical reaction. A chemical reaction is when two or more substances combine to make a new substance. The observations you made are indicators of a chemical reaction.*

2. Demonstrate the reaction again, but only use half as much of each reactant that you did the first time. You do not want the cup to overflow this time. Explain: *When you change the amount of the reactants, the reaction acts differently and produces a different amount of gas.*

3. Explain: *Chemical reactions are used in so many things in our daily lives. One is a car airbag.* Ask youth: *How does an airbag work?*

**Investigate:**

1. Tell youth: *Today, your challenge is to create a chemical reaction with our two reactants that will fill a bag completely but NOT explode the bag. You will need to keep track of how much of each reactant you add to the bag. You will only have 5 tries to get the bag fully inflated.* Show what a fully inflated bag would look like.

2. It might be helpful to demonstrate how to add the vinegar to one corner of the bag and the baking soda to the other and then seal the bag before mixing. Add 1/2 teaspoon baking soda and 2 tablespoons vinegar to a bag. As the reaction is occurring, ask: *Is a reaction happening? How do you know?* Once the reaction is complete, ask: *Is the bag full? Is there any baking soda left? How do you know?*

3. Divide youth into groups of two. Give each group a document, 5 zip-top sandwich bags, measuring spoons and cups, a cup of vinegar, and a cup of baking soda. Allow 10–15 minutes for groups to experiment with different amounts of reactants.

**Wrap-up:**

After the groups have completed their 5 trials, have them share the amounts they used in their most inflated bag. Ask: *Which reactant did you add more of? What did you consider before adding more than one ingredient? Why do you think it is important for an air bag to be fully inflated but not over inflated? Where else do you see chemical reactions? Where do you see the idea of the amount of reactants affecting the amount of products?*

## Career Connection

- Chemist and materials scientist
    - Share career profile.
    - Science in Action: Chemist: Learn about the work of chemists, various fields of chemistry, where chemists work and the types of questions they strive to answer in this interactive tutorial.
- Mechanical engineering technologists and technicians

# Activity 5: Center of Gravity

**In this lesson, youth will be able to:**

- Define center of gravity.
- Observe and explain how adding or moving weight changes an object's balance point.
- Predict how weight placement affects stability and determine why some objects tip over more easily than others.
- Design, build, and test a balanced tightrope walker by adjusting the position of weights.

**Age range:** Grades 5-8
**Time needed:** 50 minutes

## Preparation

| | |
|---|---|
| **Materials** | • Craft (popsicle) sticks (1 per youth)<br>• Pipe cleaners (1 per youth)<br>• Metal washers or clothespins (2 per youth)<br>• Toothpicks (optional)<br>• Skewers (optional)<br>• Wine cork or eraser (optional)<br>• Small objects that will adhere to skewer (marshmallows, beads, clay, etc.) |

## Facilitation

**Overview:**

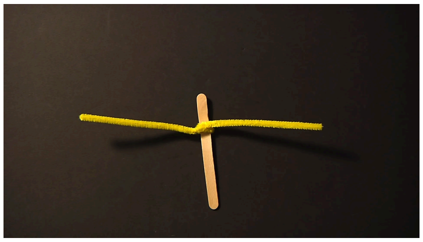
In this hands-on activity, youth investigate the concept of center of gravity by exploring balance and stability. Youth begin by balancing simple objects and observing how adding weight changes the balance point. Youth then apply their understanding to an engineering design challenge by creating a tightrope walker that can balance on the tip of a finger.

**Engage:**

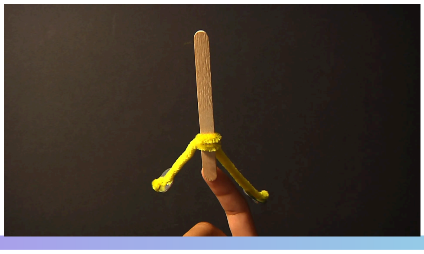
1. Give each youth a ruler, pencil, or craft stick. Challenge them to balance the object on one finger. Once they find the balance point, ask them to mark the spot on the pencil, ruler, or craft stick and compare it with a partner.
2. Tape a small object (such as a coin or paper clip) to one end and have youth try again. Ask youth to note the new balance point compared to the original.
3. Ask: *Did the balance point move? Why? Was it easier or harder to balance? What do you think makes an object tip over?*
4. Explain: *The spot where an object balances is called its center of gravity. The center of gravity is the point where an object's weight is evenly balanced. Objects with a lower center of gravity are usually more stable and less likely to fall, while objects with a higher center of gravity tip over more easily.*
5. Ask: *Where might being balanced be important?* Youth may suggest tightrope walkers, divers at the end of a diving board, gymnasts on a balance beam, etc.

**Investigate:**

1. Introduce the challenge: *Today you will create a tightrope walker that can balance on the end of your finger.*

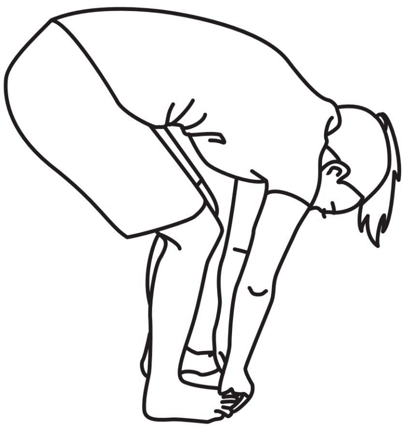


2. Distribute a craft stick, pipe cleaner, and washers or clothespins to each youth. Have youth wrap the pipe cleaner around the craft stick so that it stays in place.
3. Youth should experiment with attaching the washers to the sides of the pipe cleaner to create a balanced tightrope walker.



**Wrap-up:**

- Explain: Just like the balanced object you just created, people have a center of gravity. The center of gravity in a human is the point where your body's weight is evenly balanced. When we move our arms, bend, or change our stance, we change where our center of gravity is located. This can make balancing easier or harder. We are going to do some motions that change our center of gravity with each movement.
    - Clock exercise: Stand and shift your weight forward to your toes, back to your heels, and side-to-side. This exercise helps you map out your center of gravity and adjust your posture accordingly.
    - Squat and kicks: Start in a wide stance. Drop the hips down into a squat. As you stand up, kick one leg out to the side. This challenges your dynamic stability and requires quick center of gravity shifts.
    - Impossible leap: While standing, bend over and hold your toes with your hands, keeping your knees slightly bent. Try jumping forward in this position while holding your toes. Then try jumping backward.
        - Explanation: While bent over and holding on to your toes, you can jump backward from one end of the room to the other, but you won't be able to do a single jump forward. When you jump, you first shift your center of gravity in the direction you want to jump, and then you move your support base (i.e. your feet) in the same direction to regain your balance. When you are holding onto your toes, jumping backward is not a problem because you can use your heels to shift your weight. But to jump forward, you would have to use your toes. Unfortunately, your fingers are in the way.



    - The super glue chair: Sit in a straight-back armless chair, keeping your back against the back of the chair and your feet flat on the floor. Fold your arms across your chest. Keeping your feet flat and your back straight, stand up.
        - Explanation: While sitting in a chair with your back against the chair and your feet on the floor, your center of gravity is at your waist, supported by the chair. When you try to stand up

with your back straight, you prevent the center of gravity from moving to a position above your feet (your support base), which must happen to stand up. So you remain glued to your chair.

## Implementation

**Alternative facilitation:**

- Make the challenge more complex by having youth create a kinetic piece of art. Use a wine cork or eraser as a central point. Attach wooden skewers to the cork. Obtain a center of gravity by having youth add objects of their choice to the skewers.

**Career Connection:**

- Industrial designer
    - Share career profile.
- Soft robotics engineer: Surprisingly STEM
- Exercise physiologists (kinesiologist)

# Activity 6: Grapes and Water Density

**In this lesson, youth will be able to:**
- Design and follow an experimental procedure to determine a conclusion.
- Define density.
- Compare the density of objects to that of water.
- Use computational thinking and data.
- Construct an explanation from data.

**Age range:** Grades 3-8
**Time needed:** 50 minutes

| **Preparation** | |
|---|---|
| **Materials** | • Clear plastic glasses (3 per small group)<br>• Water<br>• Salt<br>• Measuring spoon (1 per small group)<br>• Grapes (3 per small group)<br>• Stirrer<br>• Grapes & Water Density document |
| **Setup** | • Copy the Grapes and Water Density document.<br>• Gather materials. |

## Facilitation

**Overview:**

This hands-on investigation introduces youth to the concept of density by exploring why objects float, sink, or remain suspended in water. Through an inquiry-based challenge, youth experiment with the density of different salt concentrations and the effect they have on the behavior of a grape.

**Engage:**

Fill a cup with water. Ask youth: *What will happen when I drop a grape into the water? Have youth make a prediction.* Drop the grape into the water to demonstrate that it falls to the bottom. Explain: *The grape sank because it was denser than the liquid. Density is an object's mass divided by its volume.* Ask youth to tell you other objects that sink in water. Explain: *Any object that* *sinks has a density greater than water*. Ask youth for objects that float on water. Explain: *These objects all have a density less than water. Any object that floats has a density less than water.* Ask youth: *What if an object doesn't sink but doesn't float. What if an object is suspended in the middle?* Explain: *That object has a density equal to water.*

**Investigate:**

1. Introduce the challenge: *Today, your challenge is to change the density of water so that the grape will float and sink. The way we change the density of water is by adding salt to the water. You are to determine how much salt you need to add to the cup of water to make the grape sink and to be suspended in the middle.* As a whole group, discuss ways to do this.
2. Divide youth into small groups of 2-3. Distribute the materials and a copy of the Grapes and Water Density document to each group.
3. Allow youth 10-15 minutes to experiment. Be sure groups record the number of spoons of salt added to the water.

**Wrap-up:**

1. After groups have successfully completed the task, ask them to share their data. Ask: *When the grape floats in the water, what can you tell about the density of the water compared to the grape?* Youth should say that the grape is less dense than the water. Ask: *When the grape neither sank nor floated in the water, what can you tell about the density of the water compared to the grape?* Youth should say the density of the grape and water are equal.
2. Give youth several objects to see if they sink or float in a glass of water. Have youth predict the outcome before adding the object to the water.

## Implementation

### Alternative Implementation

- Make a non-mixing liquid tower Elmers Density Column by carefully layering liquids of different densities into a clear container.

### Career Connection:

- Environmental scientist
  - Share career profile.

- Chemist
    - Share career profile.
    - Science in Action: Chemist: Learn about the work of chemists, various fields of chemistry, where chemists work, and the types of questions they strive to answer in this interactive tutorial.
- Pharmacist
    - Share career profile.

# Activity 7: Chromatography

**In this lesson, youth will be able to:**

- Design and follow an experimental procedure to determine a conclusion.
- Use computational thinking and data.
- Construct an explanation from data.

**Age range:** Grades 4-8
**Time needed:** 60-80 minutes

## Preparation

| | |
|---|---|
| **Materials** | • Coffee filter<br>• Scissors<br>• Several colors of washable markers (Black and brown markers tend to work best. Try several different brands.)<br>• Small plastic or paper cups<br>• Tape<br>• Pencils or plastic straws<br>• Water |
| **Setup** | • Cut the coffee filter into long rectangular strips, about an inch wide and 4 inches long. You should be able to cut several strips from each filter.<br>• Gather other materials.<br>• Run the mystery chromatograph with one of the markers that youth will use in the activity. (See Investigate for more information.) |

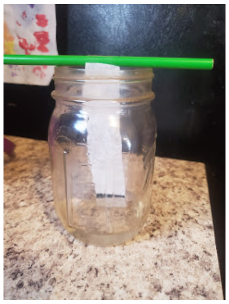
## Facilitation

**Overview:**

In this hands-on chemistry investigation, youth explore chromatography by separating the pigments hidden within different markers. After comparing the unique color patterns produced by different markers and brands, youth apply their understanding of chromatography to solve a mystery by identifying an unknown marker based on its pigment pattern.

**Engage:**

1. On each strip of coffee filter, draw a line from side to side about a half an inch from the bottom with a marker. Use a different marker for each strip. Label each strip at the top with pencil so that you know which marker was used on each strip.
2. Using a small piece of tape, attach the top of each coffee filter strip to the center of a pencil or straw.



3. Add enough water to each cup so that when you set one of the pencils or straws across the top, the coffee filter strip will just barely touch the water. Be sure that the water line is below the line you drew with the marker.
4. Allow the water to travel up the coffee filter until it has reached the top. When the water has finished climbing the coffee filter, remove it from the cup and let it dry. Compare the different pigments in different colored pens and different brands.

**Investigate**

Prior to the activity, set up the same basic chromatography experiment as above, but choose one marker ahead of time and use it to draw a line about 1/2 inch from the bottom of one of the coffee filter strips. Take note of which marker you used, but don't tell anyone else. Label this strip with a question mark. Have youth run chromatography tests on all the markers and challenge them to use the results to determine which marker was used to make your mystery line.

**Wrap-Up**

Have groups identify the unknown marker. Ask: How did you identify the marker? What was unique about the chromatograph for the unknown marker compared to the others? Can you think of any way that chromatography is used outside of this experiment? Youth may suggest forensic science, tie-dye, art, etc.

## Implementation

**Alternative Implementation:**

- Make a connection between art and science by making chromatography butterflies or chromatography flowers.

**Career Connection:**

- Forensic scientist
    - Share career profile.
    - Create a DNA Fingerprint: In this interactive activity, youth analyze simulated DNA samples to create DNA fingerprints and use genetic evidence to identify individuals, demonstrating how DNA profiling is used in forensic science and biological research.
- Chemist
    - Share career profile.
    - Science in Action: Chemist: Learn about the work of chemists, various fields of chemistry, where chemists work, and the types of questions they strive to answer in this interactive tutorial.

# Activity 8: Paper Rockets

**In this lesson, youth will be able to:**

- Use data and iteration to improve upon a model.
- Use computational thinking and data.
- Construct an explanation from data.

**Age range:** Grades 3-8
**Time needed:** 50 minutes

| Preparation | |
|---|---|
| **Materials** | • Plastic straws<br>• Tape<br>• Glue<br>• Various types of paper (tissue, copy, construction, card stock)<br>• Scissors<br>• Measuring tape or meter stick<br>• Paper Rocket Data Log |
| **Set Up** | • Copy the Paper Rocket Data Log.<br>• Cut paper the length of the straw.<br>• Establish a landing zone by taping off an area in the room that the rockets will be required to land within. |
| **Presentation** | Slides |

## Facilitation

**Overview:**

In this activity, youth explore the science of rocket flight by creating and testing their own straw rockets. Youth will use the engineering design process to build, test, and improve rocket prototypes, investigating how design features such as fins, size, and materials affect stability and distance.

**Engage:**

1. Show the video (Slide 2) Artemis II Launches Astronauts to the Moon. Discuss youth reactions to the video and to space travel in general.
2. Explain that today youth will make their own straw rockets to model how engineers designed the rockets for Artremis.

**Investigate:**

1. Demonstrate how to make a straw rocket and launch it.
    a. Roll a piece of paper around a pencil to create a tube.
    b. Apply a small piece of tape to hold the tube together.
    c. Close the top of the tube with scotch tape.
    d. Insert a plastic straw and blow to launch the rocket.


2. Ask youth: *What is my rocket missing that many rockets have? What is the advantage of having fins on the rocket? Do you think I could make my*

*rocket travel further? How? Does the appearance of my rocket look similar to the one we saw in the video? Besides the fins, what else is different?*

3. Explain the challenge to the group (Slide 3): *Design a straw rocket that will travel furthest in a straight path.*
4. Depending on the previous experience of youth, introduce or review the engineering design process (Slide 4). Explain: *The engineering design process is a problem solving method. It can be used to solve big problems like building a space capsule or smaller problems like building a paper rocket. By following the steps, you will be able to complete almost any task.*
5. Explain: *Criteria are things that must be included or that the rocket must do. Constraints are the limits or things that can not be included or done to the rocket* (Slide 5). Reveal the criteria and constraints.
    a. Criteria
        i. Your rocket must be launched from a straw.
        ii. It must land in the landing zone.
        iii. Flight measurements will be taken from the launch area (toe of the launcher) to the tip of the stopped rocket.
    b. Constraints
        i. You may only use the materials provided to your group.
6. Divide youth into small groups. Distribute the materials. Allow 15–20 minutes for groups to build a prototype. During this time encourage youth to build, test, and redesign as needed. Have each group keep track of their designs in the data log (Slide 6). As youth work, circulate around the room and assist by asking groups some guiding questions, such as: *Have you tried different kinds of paper? Did the size of the fins affect the distance? Did the size of the rocket affect the distance?*

**Wrap-up:**

Bring the whole group back together for the blast off. Line up one member from each group with their rocket approximately 5–6 feet from the landing zone. Have all groups launch their rockets at the same time to determine who met the challenge. After the launch, examine any rocket that landed in the landing zone and discuss the similarities and differences in the designs. Ask what important characteristics were needed for a successful rocket. Ask each group how they think they could make their rocket even better.

## Implementation

**Alternative Implementation:**

- Have each group measure the distance that their rocket traveled. Compile the total distance that all the rockets in the group traveled. Calculate the average distance that the rockets in the group traveled.
- Move the landing zone further away. Retest the rockets to see if they can travel a longer distance

**Career Connection:**

- Aerospace engineer
  - Share career profile.
  - A Day in the Life of an Aeronautical Engineer: An interactive story for youth to explore the decisions an aeronautical engineer might make when designing various flying technologies.
- Wind tunnel engineer
  - Surprisingly STEM
- Satellite technologist
  - Share career profile.

## Activity 9: AI & Machine Learning

**In this lesson, youth will be able to:**

- Define artificial intelligence (AI).
- Explore algorithms by categorizing objects based on a set of rules.
- Gain an understanding of the basics of what machine learning is and how it can be used to identify objects.

**Age range:** Grades 5-8
**Time needed:** 50 minutes

## Preparation

| | |
|---|---|
| **Materials** | • Laptop or computer<br>• Set 1 cards and Set 2 cards<br>• Monarch butterfly algorithm |
| **Set-up** | • Print and cut Set 1 cards. (1 set per small group)<br>• Print and cut Set 2 cards. (1 set per small group)<br>• Print algorithm. (1 per small group) |
| **Presentation** | Slides |

## Facilitation

**Overview:**

This hands-on activity introduces youth to artificial intelligence and machine learning by having them act as an AI system trained to identify monarch butterflies using image cards and an algorithm. As youth test and refine the algorithm with new data, they discover how AI learns from patterns, improves over time, and can still make mistakes.

**Engage:**

1. Ask youth to define or describe artificial intelligence. Say: *What is artificial intelligence?* After several ideas have been shared, consolidate thoughts into a conclusion, such as: *Artificial intelligence is the ability of a digital computer or computer-controlled robot to perform tasks commonly*

*associated with intelligent beings. The term is frequently applied to the project of developing systems endowed with the intellectual processes characteristic of humans, such as the ability to reason, discover meaning, generalize, or learn from experience.* (Definition from [britannica.com](britannica.com).) (Slide 2)

2. Ask youth: *How have you used AI?* Some youth may have used Chat GPT or Gemini. Also mention Alexa, Siri, Netflix or Spotify's ability to recommend shows or music based on your preferences, GPS for directions, and even Uber's ability to match a driver to a rider. Highlight that AI is also used for (Slide 3):

    a. Visual recognition, such as facial recognition and visual image search

    b. Speech recognition, such as Siri and Alexa

    c. Machine translation, such as Google Translate

3. Ask youth: *What is machine learning?* After several ideas have been shared, state: *Machine learning is a branch of AI where the goal is to create a program that improves over time or "learns" as it processes more data* (Slide 4).

4. Ask youth: *How do machines learn?* Explain that engineers provide training data (e.g., numbers, photos, text) which the AI uses as the basis for an algorithm. An algorithm is the set of rules a machine uses for making classifications or predictions. Engineers then provide more data, rules, or both to test or adjust the algorithm to ensure that it is performing accurately. Some examples of machine learning are self-driving cars and recommendation systems, like you might see while using Netflix or shopping on Amazon.

**Investigate:**

1. Say: *Today you are going to act as a machine. Engineers are going to train you to recognize an object based on an algorithm. Set the scenario: A group of environmentalists set up a small camera in the garden to see if their flying visitors are monarch butterflies or other insects. Monarchs are important pollinators that help plants grow and spread, and they also serve as an indicator of a healthy environment. Protecting monarchs supports the balance of many ecosystems. You, as the computer, need to recognize any monarch butterfly that visits the garden* (Slide 5).

2. Divide youth into pairs. Give each group a set of image cards (Set 1) and the algorithm to follow to identify the images (Slide 6). Show youth the cards and read the algorithm aloud so all understand the rules of

identification. Tell youth: *You will have 5 minutes to sort the cards into two piles using the algorithm. Remember that the algorithm contains the only rules that the AI program understands, so you must follow them. You cannot use your own existing knowledge of the pictures.The algorithm may be imperfect or lead to errors. That is OK. You should notice the errors but not correct them.*

3. When time is up, have pairs share the images they put in each pile. Discuss any differences that groups have and why. Ask: *How did you decide if the image belonged to Group A or B? How many images were categorized correctly based on the AI algorithm? How helpful was the AI's algorithm? What is the difference between how people see and how AI or machines see? How does the algorithm need to change in order to further separate the images?*

4. As a whole group, rewrite the algorithm to include youth's suggestions (Slide 7). If youth have difficulty, suggest one or more of the following:

    a. Group A: when resting, the wings are folded; wings are orange and black; smooth body

    b. Group B: when resting, wings are spread; wings are colors other than orange and black; hairy body

5. Distribute Set 2 of the image cards and direct youth to add these new cards to the original set. Give pairs 5 minutes and the new algorithm. Have youth sort the images into two groups once again. After time is up, discuss if the sorting went better. Ask: *Did any images that were originally in Group A move to Group B? How did you decide if the image belonged to Group A or B? How many images were categorized correctly based on the AI algorithm? How helpful was the AI's algorithm?*

**Wrap-up:**

Ask youth: *What did you learn about machine learning? Is every answer that comes out of AI correct? How detailed does an algorithm, or set of rules, need to be to increase accuracy? When training AI models, what is important to keep in mind?*

## Implementation

**Alternative facilitation:**

- Consider a digital option to this activity. In the [Can AI Guess Your Emotion?] activity, youth explore image classification using [Google's Teachable Machine]. Youth consider how facial features help us recognize emotions and train an AI tool to recognize these. Youth can also expand on this activity by exploring training an AI tool to recognize pets, words, or other types of data. Digital devices are required for this activity.

**Career Connection:**

- Which area of tech should you study? quiz
- Careers in AI Video Series
- Careers with STEM: AI & Robotics
- Data scientist
    - Share career profile.
    - Could I be a data scientist? quiz
- Cybersecurity specialist

# Activity 10: Biggest Splash

**In this lesson, youth will be able to:**

- Use the engineering design process to complete a design challenge.
- Understand the difference and importance of constraints and criteria.
- Investigate how an object's size, shape, and mass affect water displacement.
- Communicate and collaborate with peers to reach a goal.

**Age range:** Grades 3-8
**Time needed:** 50 minutes

## Preparation

| | |
|---|---|
| **Materials** | • Plastic cup (1 per small group)<br>• Water<br>• Ruler (1 per small group)<br>• 200 mL graduated cylinder or measuring cups (1 per small group)<br>• Tray to catch spilled water (1 per small group)<br>• Aluminum foil<br>• Craft sticks<br>• Small items such as beads, plastic eggs, metal washers, metal screws, and marbles<br>• Biggest Splash document<br>• Video: How Olympic Divers Make the Perfect Tiny Splash<br>• Video: How Do You Perform the Perfect Dive<br>• Video: Everything You Need to Know About Diving |
| **Setup** | • Copy the Biggest Splash document.<br>• Gather all materials and set up a materials hub. |
| **Presentation** | Slides |

## Facilitation

**Overview:**

In this engineering design challenge, youth compare the characteristics of professional divers with the design of an object intended to create the biggest possible splash. Using the engineering design process, participants brainstorm, build, test, and redesign a "diver" while collecting and analyzing data to determine which design displaced the most water.

**Engage:**

Show one of the recommended videos describing successful diving or find one of your own (Slide 2–4). After watching the video, discuss what characteristics are important in making the perfect dive. Youth may share many ideas from the video. Be sure to stress that making a small splash is important. Discuss how successful divers are able to make the smallest splash.

**Investigate:**

1. Depending on the previous experience of youth in your group, introduce or review the engineering design process (Slide 5). Explain the engineering design process is a problem-solving method. It can be used to solve big problems like building a space capsule or smaller problems like building a paper tower. By following the steps, you will be able to complete almost any task.
2. Share the challenge: *Design a diver that creates the largest splash (Slide 6). Based on what you just learned about diving, what kinds of characteristics might your diver have?* Allow several youth to share their ideas.
3. Show youth the materials that are available to them in the materials hub.
4. Explain: *Criteria are things that must be included or that the diver must do. Constraints are the limits or things that can not be included or done to the diver* (Slide 7). Reveal the criteria and constraints.
    a. Criteria:
        i. Splash as much water out of the cup as possible.
        ii. The diver must completely fit into the cup.
    b. Constraints:

    i. May only use the materials provided in the materials hub.

5. Divide youth into groups of 3 and distribute the Splashy Science document to each group. Allow 5 minutes for groups to brainstorm and draw an initial diagram of their diver.

6. Allow youth 15–20 minutes to build their diver, test, and redesign as needed. Youth can test the diver's ability to splash using the cups on trays.

**Wrap-up:**

1. Bring all groups together and have each group describe their diver. Then hold a diving contest. Use a graduated cylinder to pour 200 mL of water into each team's cup. If you do not have a graduated cylinder, use a measuring cup to add the water. Drop the diver from the same height above each cup and drop it. Pour the remaining water from the cup into the graduated cylinder or measuring cup to determine how much water remains. Have youth record results on the Splashy Science sheet as you go (Slide 8). Calculate how much water splashed out.

2. Discuss the design of the diver that splashed out the most water.

## Implementation

**Alternative Implementation**

- Have youth redesign a new diver that will create the smallest splash.
- Perform the same diving contest from a greater height to see if the splash remains the same.
- Add some math to the calculations by determining the percent of water that remained in each cup and the percent of water that splashed. Make a bar graph of the amount of water that each group splashed.

**Career Connection:**

- Physical therapist technician
    - Share career profile.
- Data scientist
    - Share career profile.
    - Could I be a data scientist? quiz