



CURTIS RISING STARS
— A Science Challenge for K-5 —

2020-2021

Pre-Activity Curriculum Guide
Level: Advanced

Curtis Rising Star Science Challenge

Program Summary

This is an entry-level STEM competition for students in grades Kindergarten – 5th. The purpose of this program is to prepare and inspire elementary students for science competitions later on in their academic careers.

The premise of this competition is challenge-based with a team focus. Unlike middle and high school competitions, this program will seek to prepare students through pre-activities and prompts that occur during the school day and then culminates in a daylong event at the Orlando Science Center where students will put their skills into practice via a competition.

Objective

The Science Center challenges young elementary student teams of 2 – 5 students (grades K-5) to practice skills in their classroom and apply them via a competition, with the support of their educators, support networks, and families, at the Orlando Science Center.

Content:

Topic	Page
Using This Curriculum Guide	5
Processes of STEM	6
The Scientific Method	
The Engineering Design Process	
Student Success in STEM Activities	11
Curtis Rising Star Science Challenge Rubric	
Pre-Activity 1: Scaffolding System	13
Students design a scaffolding system that must be a minimal height and support a minimal mass.	
Pre-Activity 2: Design a Roller-Coaster	28
Students design a roller coaster track for a marble that must be safe and meet specific design criteria.	
Pre-Activity 3: Design Play Dough	40
Students design a process to create high-quality play dough.	
Pre-Activity 4: Water Runoff Reduction	50
Students design a system which efficiently reduces water runoff in a model urban landscape.	
Pre-Activity 5: Design a Zip Line	62
Students design a vehicle that can traverse a zip line and deliver a payload to a destination.	
Pre-Activity 6: Design a Paper- Copter	72
Students design a paper-copter which will use drag to descend to the ground as slowly as possible from a given height.	
Pre-Activity 7: Design a Telephone	93
Students design a telephone which transfers sound clearly.	
Pre-Activity 8: Plant Hydrating System	102
Students design either a filter or hydroponics system.	
Pre-Activity 9: Board Game Challenge.....	116
Students design a board game in which they will need to solve math equations.	



**ORLANDO
SCIENCE
CENTER**

Pre-Activity Standards	123
------------------------------	-----

Using This Curriculum Guide

This guide contains nine pre-activities which tie in K-5 science standards. Please choose five of these pre-activities to complete with your students. These activities are meant to prepare students to apply relevant math and science concepts while thinking critically, collaborating, communicating, and using their own creativity. These are the skills students will be judged on at the Curtis Rising Star Science Challenge.

Each pre-activity has been written with adaptations to make the lesson more basic or more advanced. Educators should read over the curriculum and decide which adaptations will meet the needs of their students' learning levels. These adaptations are merely suggestions to help educators scaffold student learning and are by no means the only adaptations that can be made. Educators should use their own judgment as to what additional instructional strategies will be appropriate for their students' needs.

Activity timing and materials have been estimated, but should be adjusted according to your schedule and the needs of your students. Constraints should not be so light that the activity is too easy, but also should not make the activity so challenging that it becomes frustrating for the students. Constraints have been suggested to make the activities challenging, but should be changed as necessary. If it becomes obvious during the activity that it is too easy or too difficult for your students, extend or shorten time or give groups more or less materials as needed.

An advanced and basic engineering notebook has been provided. There are pages which accompany each of the pre-activities. This is not meant to hand students as one packet—rather, give students the pages they need for each activity. The notebook has been provided to help facilitate the activity and guide student understanding but, is not required. If printing is limited at your school, have students record their ideas, process, and reflection on notebook paper instead.

Processes of STEM

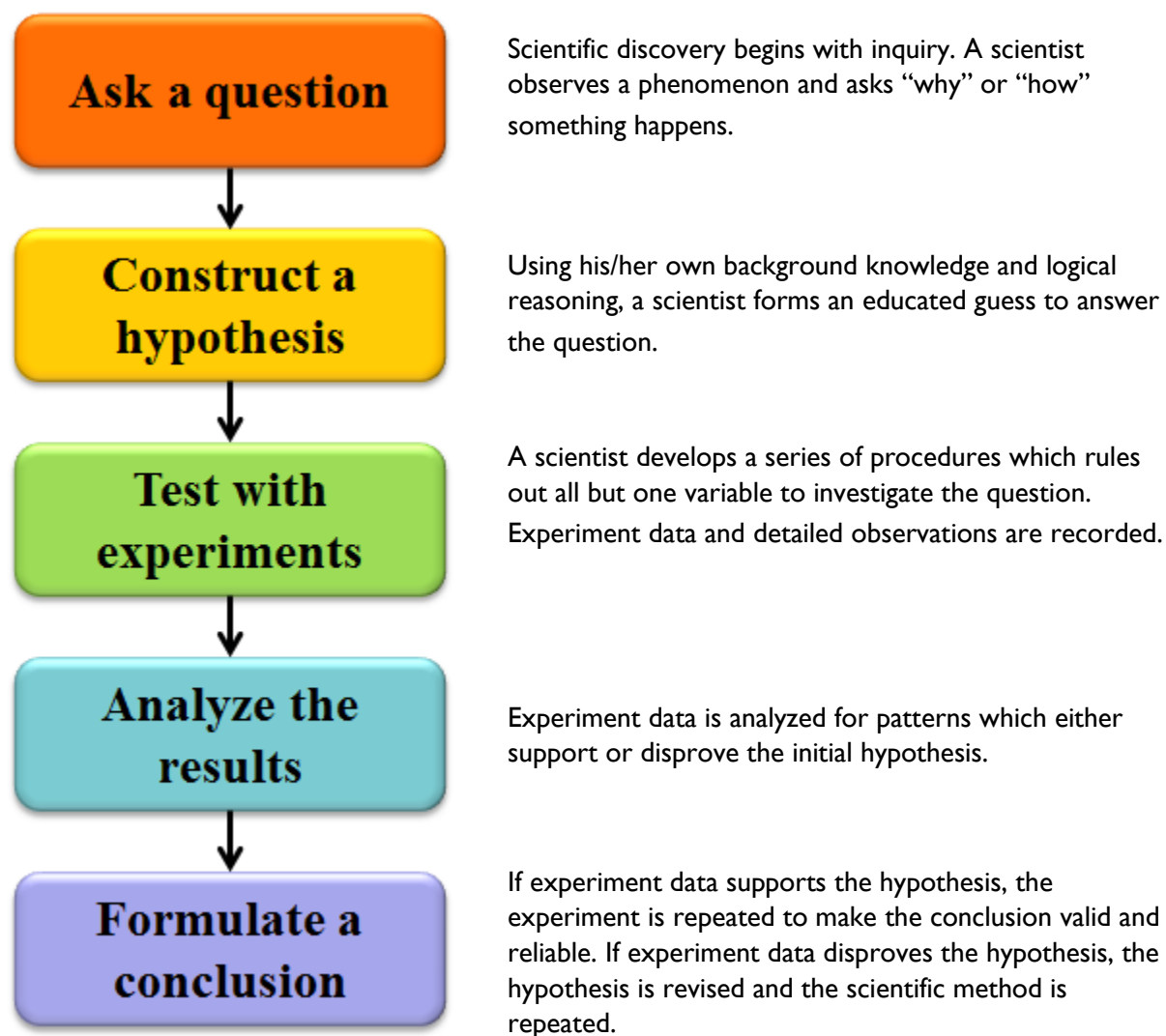
STEM education is an interdisciplinary approach to learning, combining multiple academic subjects, focusing on the real-world impact of these lessons. It is about students applying science, technology, engineering, and mathematics in contexts that make relevant connections between themselves and their school, community, work, and their world. STEM education provides opportunities to create skills that move students forward to become stronger problem solvers and more creative innovators that can lead tomorrow's global economy.

The pre-activities in this guide will equip students with the skills and tools they need to apply science and math concepts as they utilize their creativity and collaborate with peers to solve real-world problems.

The Engineering Design Process and Scientific Method are two processes students should be familiarized with before beginning the pre-activities in this guide. This section will provide a brief overview of each, highlighting the differences between the two processes.

The Scientific Method

The scientific method is the process by which scientists investigate the natural world and attempt to develop logical explanations.



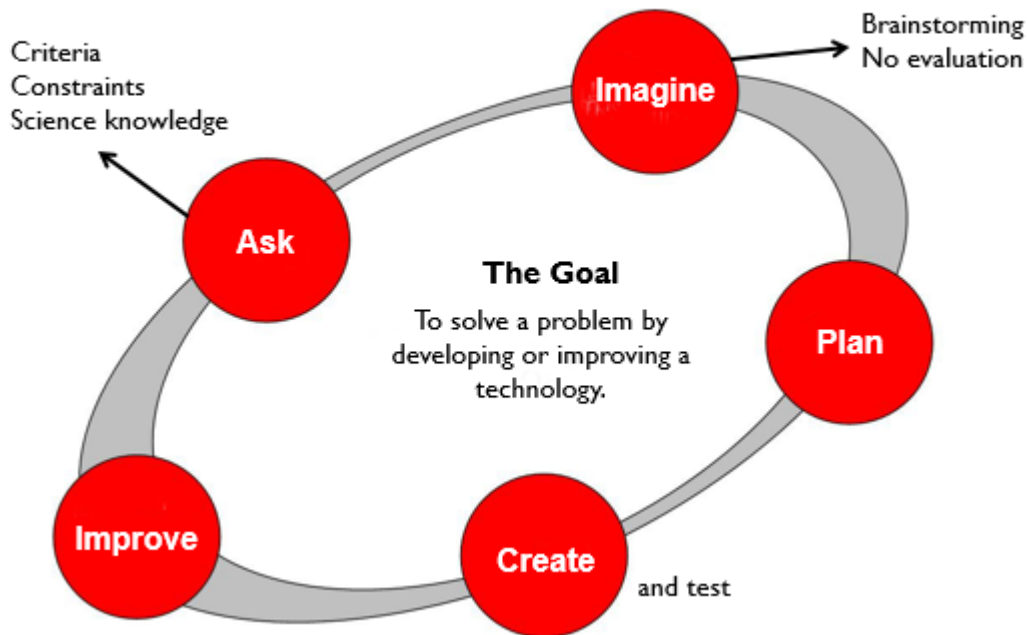
* Source: getchemistryhelp.com

Scientific Method Activity Resources:

If you have not yet covered the Scientific Method with your students, the following resources contain activities meant to introduce students to the Scientific Method and guide them through scientific investigations.

- Source: Pennsylvania Department of Education, Standards Aligned System (SAS)
<http://www.pdesas.org/module/content/resources/16037/view.ashx>
“Double Bubble Science”
Grade Level: K – 2
In this lesson, students will understand how to use the scientific method to find answers to questions by investigating how household items create bubbles.
- Source: Shraddha Subramaniam, Summer Research Program for Science Teachers, Columbia University
<http://www.scienceteacherprogram.org/genscience/SSubramaniam09.html>
“Testing the Scientific Method Through Thumb Wars”
Grade Level: 3 – 4
Students will have an opportunity to go through the entire process of the scientific method using the game "Thumb Wars".

The Engineering Design Process



* Source: Engineering is Elementary

ASK questions that will help you achieve your goal.

- What are the criteria my design needs to meet?
- What are the constraints which limit me?
- What science and math content will I need to consider as I design my technology?

IMAGINE at least two possibilities for design.

- What could be some solutions?
- Brainstorm ideas.

PLAN the design before building.

- Collaborate with my team to make a plan for our design.
- Make a list of the materials needed.

CREATE at least one design solution.

- Follow the plan and create it.
- Test design and evaluate results.

IMPROVE the design based on evidence around the original design criteria.

- Make the design better.
- Re-test and evaluate results.

Engineers are people who use their knowledge of math and science, as well as their own creativity, as they create and improve technology to solve problems. The Engineering Design Process is a tool engineers use when developing new technology or improving existing technology.

Scientific reasoning is used during an engineering challenge however, the Engineering Design Process is different from the Scientific Method:

- In a scientific inquiry, an answer to a question is investigated and this answer is determined from gathered evidence either to be correct or incorrect. The goal of a scientific inquiry is to understand the natural world around us by forming logical explanations. The scientific method is often a part of engineering as engineers *ask* questions to gather scientific data they will need to consider as they create their designs.
- In the Engineering Design Process, there is not a correct answer but instead infinite possible solutions to a problem. An engineer uses creativity as he/she creates one possible solution to this problem and considers math and science in order to determine whether the design is an efficient solution to the problem. The goal of engineering is to design technology which solves a problem or fulfills a desire.

Engineering Design Process Activity Resource:

If you have not yet covered the Engineering Design Process with your students, the following resource contains an activity meant to introduce students to the Engineering Design Process and guide them through engineering activities.

- Source: Engineering is Elementary (EiE)
www.eie.org
“What is Engineering? Tower Power”
Grade Level: K – 5
Students become familiar with the Engineering Design Process as they engage in a common engineering design challenge.

Student Success in STEM Activities

In STEM activities, student success is not measured merely by the final product and whether or not it has achieved the design goal. Student success is measured through the process students follow as they attempt to solve problems and their ability to apply 21st-century skills.

In the Curtis Rising Star Science Challenge, student success will be measured using the following criteria:

- **Student Application of 21st Century Skills**

Students will be assessed on the level they were able to apply these four 21st century skills as they created a solution to a problem.

- *Critical Thinking:* Does the student attempt solutions to the problem based on logical reasoning? Does the student analyze failure and consider test data to improve a design?
- *Collaboration:* Does the student communicate efficiently with his/her teammates both by effectively relaying his/her own ideas and by listening to and considering ideas from teammates? Is the team able to come together to formulate a design?
- *Communication:* Can the student explain the reasoning behind design choices? Can the student justify whether a design has or has not met the design criteria?
- *Creativity:* Is the student able to come up with original ideas or ways to improve existing ideas?

- **Student Application of Math and Science Concepts**

- *Understanding:* Does the student convey an understanding of relevant math and science concepts when communicating justification of design choices and evaluation of design performance?
- *Application:* Does the student apply content knowledge by considering relevant science and math concepts while making design choices, evaluating design success and failure, and improving a design?

The following pages contain the rubric with specific criteria that will be used when judging student designs at the Curtis Rising Star Science Challenge. Educators should use this rubric when evaluating student success in the pre-activities in order to familiarize themselves with it and in order to prepare students for what will be expected from them at the event.

Curtis Science Challenge Student Success Rubric

Success Criteria	1- Beginning	2- Developing	3- Practicing
Critical Thinking The student team will design a solution to the problem using logical reasoning and attempt re-design using information gathered from testing.	<ul style="list-style-type: none"> ✓ No attempt to solve the problem ✓ No attempts to re-design 	<ul style="list-style-type: none"> ✓ Attempts to solve problem. ✓ Attempts to re-design 	<ul style="list-style-type: none"> ✓ Attempts to solve problem with logical reasoning ✓ Attempts to re-design based on all information gathered from testing
Collaboration (amongst team) The student team will explain ideas to one another while listening and coming together to formulate a single design.	<ul style="list-style-type: none"> ✓ No attempt to explain ideas ✓ Not listening ✓ No attempt at one group design 	<ul style="list-style-type: none"> ✓ Attempts to explain ideas ✓ Listen, but often argue or interrupt each other. ✓ Attempts group design, no clear decision made. 	<ul style="list-style-type: none"> ✓ Attempts to explain ideas and explanations are understood ✓ Listen to one another. ✓ Attempts group design, decided upon together.
Communication (with Judges) The student team explains reasoning behind design choices and can justify why a design has or has not met the design criteria.	<ul style="list-style-type: none"> ✓ No explanation behind design choices ✓ No justification whether a design has or has not met the design criteria. 	<ul style="list-style-type: none"> ✓ Unclear or incomplete explanations of design choices. ✓ Partially justify whether a design has or has not met the design criteria. 	<ul style="list-style-type: none"> ✓ Clear and complete explanations of design choices. ✓ Justify whether a design has or has not met the design criteria.
Creativity The student team displays original ideas or ways to improve existing ideas.	<ul style="list-style-type: none"> ✓ No original ideas or ways to improve existing ideas 	<ul style="list-style-type: none"> ✓ One original idea or way to improve an existing idea 	<ul style="list-style-type: none"> ✓ Three or more original ideas or ways to improve an existing idea
Content Understanding The student team conveys understanding of relevant math and science concepts related to the challenge.	<ul style="list-style-type: none"> ✓ Conveyed no understanding of relevant math and science concepts 	<ul style="list-style-type: none"> ✓ Conveyed <i>minimal</i> understanding of some relevant math and science concepts 	<ul style="list-style-type: none"> ✓ Conveyed <i>complete</i> understanding of all relevant math and science concepts
Content Application The student applies relevant math and science concepts related to the challenge and their design/improvement choices.	<ul style="list-style-type: none"> ✓ No application of relevant math and science concepts related to challenge and their design/improvement choices 	<ul style="list-style-type: none"> ✓ <i>Minimal</i> application of relevant math and science concepts related to challenge and their design/improvement choices 	<ul style="list-style-type: none"> ✓ Application of relevant science and math concepts related to challenge and their design/improvement choices

Scaffolding System

Prep: 5 – 10 min.

Activity: 65 min.

Science Topic: Force and Motion

Learning Objectives: Students will...

- Explore how to create structures that will stand against the pull of gravity.
- Investigate how objects are affected by incrementally increasing force.
- Use empirical evidence to explain why a force has a greater or less effect on structures.

Vocabulary

- gravity
- force
- stability
- strength
- structure
- balance
- failure
- two-dimensional shapes
- three-dimensional shapes
- mass
- scaffolding

Overview

In this pre-activity, students explore the effects of the force of gravity on structures. Students use the engineering design process to find a possible solution to the problem: Create a structure of a specific height which is strong enough to overcome the force the gravity.

Students must collaborate with their peer(s) to design a model scaffolding structure which will meet their developmentally-appropriate criteria. Students will use developmentally-appropriate measuring tools to determine whether their structure has met the criteria, and whether their second prototype has improved in meeting this criteria.

Students work within materials and time constraints as they attempt to solve the problem. Students receive a set number of developmentally-appropriate building materials and create, test, and improve their designs. Students evaluate their designs to determine whether they have met the goal criteria.

Students share their design with their classmates and compare different designs to appreciate the creativity that goes into engineering.

Background

A **force** is a push or a pull on an object. When a force increases or decreases in its push or pull on an object, it causes a change in motion in that object. Objects may accelerate, slow down, or change shape. The greater the amount of force applied, the greater the effect will be on an object's motion.

Mass is how much matter is contained in an object. **Gravity** is the force of attraction between objects that have mass. All objects that have mass exert a gravitational pull. Objects with greater mass have greater gravitational force than objects with less mass. Since the earth is so much larger than the objects on it (i.e. you and me, plants, animals, buildings), all of the objects on earth are pulled toward the center of the earth.

Engineers need to consider the earth's gravitational pull when they are designing **structures**. If a structure does not have the necessary aspects needed to stay standing, it will **fail** and give in to the pull of gravity toward the earth's surface.

- Structures need to be **stable** enough not to change in shape when gravity pulls on them.
- Structures need to be **strong** enough to stay standing and keep from being pulled to the earth's surface.
- The gravitational pull must be **balanced** in a structure so it is not pulling on one portion more than another, which could cause the structure to fail.

Engineers also need to consider geometrical shapes when creating structures. Using certain **two-dimensional** shapes as building blocks can strengthen the integrity of a **three-dimensional** shape.

- Triangles provide strengthening ability for structures.
- Arches and domes use compression to their advantage to strengthen structures.
- Increasing horizontal surface area at the base strengthens a structure by spreading out where gravity is pulling on.

Scaffolding is a temporary structure used to support construction workers and materials as they are constructing, repairing, and or maintaining permanent structures such as buildings and bridges. Scaffolding can be made out of different kinds of materials, but usually consist of support beams with connector joints.

Resources

For more information, please access the following resources:

- Kids Discover
"Spotlight: Force and Motion"
<http://www.kidsdiscover.com/spotlight/force-motion-kids/>

Pre-Requisite Knowledge

Students should have grade-appropriate comprehension of the following concepts:

Basic (students do not necessarily need to be able to do these independently)

- How to measure with a ruler (or with non-standard units of measurements, whichever is the grade level's standard)
- A basic understanding that gravity is the force that pulls objects toward the earth's surface
- A force is a push or pull on an object that can change how the object is moving
- Connecting counting and cardinality
- Either the ability to "count on" and "count back" or add and subtract
- Basic two-dimensional shapes
- Comparing greater than, less than, and equal to

Advanced

- How to measure with a ruler to the nearest $\frac{1}{4}$ inch
- An understanding of what gravity is and how objects can overcome it
- An understanding of basic units of measurement for mass (grams)
- How to present information in a bar graph
- Addition, subtraction, and multiplying numbers by a single-digit number
- How to calculate area and perimeter for two-dimensional shapes
- How two-dimensional shapes can be put together to form three-dimensional shapes

Pre-Requisite Resources: The following resources provide activities for educators who have not yet covered pre-requisite science concepts in the classroom:

- Force
"Push and Pull"
<http://www.cpalms.org/Public/PreviewResourceLesson/Preview/46809>
- Gravity
"Look Out Below!"
<http://www.cpalms.org/Public/PreviewResourceLesson/Preview/11514>

Materials

For the Class:

- Engineering Design Process (on the board or on chart paper)
- large textbook, approx. 10" x 11 1/2"
- 8 oz. plastic cup
- approx. 100 small objects of the same mass (i.e. hex nuts, gram units, marbles)
- balance or digital scales (measures in g)
- Examples of Scaffolding Systems

For Each Group of 3 – 4 Students

- 53 sheets of 8 1/2" x 11" copy paper (can be recycled)- **tip: use recycled paper**
- 23 pipe cleaners
- scissors
- single hole punch
- 3 1/2 ft. masking tape
- ruler marked in inches, 1/2 inches, and 1/4 inches
- markers/crayons

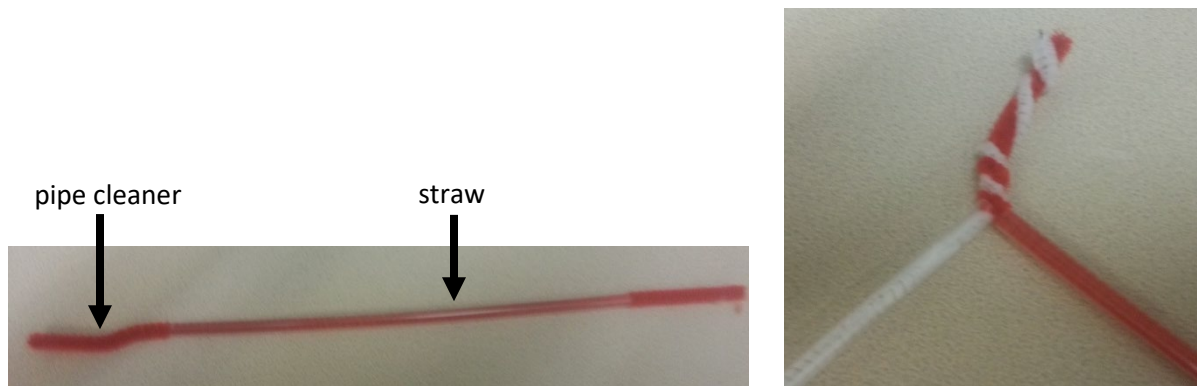
For Each Student

- pencil
- advanced engineering notebook

Prep

- How to create columns and joints
 - Thread a pipe cleaner through a straw. The edges of pipe cleaner should poke out of either end of the straw at least an inch.

- You can twist one end around the pipe cleaner in another straw to create a joint.



- How to create columns and joints
 - Line a pencil up with the edge of the paper. Make sure the eraser sticks out over the edge a little so you can pull it out later.
 - Roll the paper to form a cylinder around the pencil.
 - Use a small piece of masking tape to secure the paper in the cylindrical shape. Pull the pencil out.
 - Use a hole punch to punch a hole through either end of the column.
 - Cut a piece of pipe cleaner a few inches long and thread it through either end. You can twist one end around a pipe cleaner in another column to form a joint.
- Use the scale to find the mass of the textbook in grams. Write it on the board or on chart paper where students can see. Use the scale to measure one of the 100 small objects of the same mass (i.e. hex nuts, gram units, marbles) in grams. Add the mass of one of these objects to the board or chart paper.



Introduction (15 min.)

1. Review with students what they have learned about force and motion. Ask:
 - **What is a force?** *(A force is a push or a pull that may change the motion of an object.)*
 - **What is the force that pulls objects toward the surface of the earth?** *(gravity)*
 - Expand the definition of gravity to include the relationship between mass and gravitational pull.
2. Lead the students in a discussion about how objects can overcome gravity. Ask:
 - **What objects do you see in the classroom that are standing up, even though gravity is pulling them toward the ground?** *(Possible answers may include: Tables, chairs, the walls, computers, people)*
 - **These objects are rather small. Have you seen large objects in real life that stand up to gravity?** *(Possible answers may include: Buildings, skyscrapers, bridges, trees, billboards)*
 - **How do these objects stand up to the force of gravity?** *(Call on a few students to share their ideas.)*
3. Ask the students if they have ever heard of “scaffolding.” Show the students images of scaffolding and ask students if they have ever seen structures like this before outside of a building or bridge. Explain that scaffolding is a temporary structure that supports construction workers and materials as a permanent structure- like a building or bridge- is being built, maintained, or repaired.
4. Review with students what engineering is. Ask:
 - **What is an engineer?** *(An engineer is a person who uses his or her creativity and knowledge of science and math to design and improve technology to solve problems.)*
 - **What is the process that engineers when they are designing and improving technology?** *(Review each step of the engineering design process. The process should be written on the board or on chart paper for students to see.)*
5. Explain to the students that they are going to be engineers who will be solving a problem using the engineering design process. Tell the students the problem and goal, and write the goal on the board:
 - **Problem:** A construction company needs a new scaffolding design to support materials and workers as they make repairs on an old building.
 - **Goal:** Design a scaffolding system that is tall and stable enough for the workers to reach the top floor of the building. The building must be strong enough to support the mass of the workers and building materials.

6. Ask the students: **“Now that we have our goal, where should we start in the engineering design process?”** *(We should ask questions to identify criteria and constraints as well as to explore any science and math content we will need to know to solve the problem.)*
7. Record students’ questions on the board. Make sure the following questions end up on the board:
 - **How tall is the top floor of the building?**
 - **What is the mass of the workers and materials our scaffolding system needs to support?**
 - **How will we know if our scaffolding system is stable?**
 - **How wide does our scaffolding system need to be?**
 - **How long does the scaffolding system need to stand for?**
 - **How long will we have to create our designs?**
 - **What materials can we use?**
8. After students have finished brainstorming questions, answer each of them. Record criteria and constraints on the board or on chart paper. Students should record the criteria in the appropriate places in their notebooks.
 - **Height:** 6 inches- students will measure to the nearest whole in.
 - **Mass:**
 - **The mass of the workers is the mass of the textbook** (or journal, if you are teaching the basic version.) This is the minimum mass the scaffolding system must be able to support. Pass around the book for students to feel the weight. Share the actual mass in grams of the textbook and one of the “building materials” with students.
 - **Each object from the 100 small objects of the same mass represents one building material.** We will place one building material at a time in a cup on top of the book to see how many building materials the scaffolding system can support. Pass around one of the objects for students to feel.
 - The structure must be able to support the mass of the workers (book) for at least 30 seconds.
 - Then we will add one “building material” at a time to the cup on top of the book, 10 seconds each, to see how much additional mass the structure can support.
 - **Stability:**
 - The scaffolding system is stable if it can balance on its own, without someone holding it up.
 - **Width:**
 - Share the length and width of the book representing the mass of the workers with the students. The top of the scaffolding system must be able to support

this length and width. Show the students the spot in their notebooks where they will record the perimeter of the top of their scaffolding system.

- Have students calculate the surface area of the text book.
- **Time:** (show the students each corresponding page in their notebooks)
 - Each student will have 5 min. to imagine ideas in their notebooks.
 - Teams will then collaborate for 5 min. to develop a plan.
 - Once the plan has been approved by the teacher, teams will have 15 min. to create their designs. Any changes to the designs should be reflected in the plan.
 - We will test the height, strength, and stability of our designs.
 - Teams will then have 10 min. to improve their designs.
 - We will test the height, strength, and stability of our improved designs.
- **Materials:** Show the students how to use their grade-appropriate materials. Explain to the students that they will receive a sample of materials to use during their imagining and planning time to experiment with.
 - Students will receive 50 sheets of 8 ½" x 11" copy paper, 20 pipe cleaners, scissors, a single hole punch, 3 ft. of masking tape, and a ruler.
 - Show students how to create a support column (see prep). Point out that students may roll columns narrower or wider if they want to. They may also cut the columns shorter if they like.
 - Show students how to create a connecting joint (see prep). Explain that students may use the pipe cleaners for other creative ideas they may come up with, as well.
 - If students finish early, they may use crayons/markers to decorate their scaffolding system.

Activity (45 min.)

1. Have students remind you of the next step in the engineering design process. (*imagine*) Explain that students should be imagining individually and not talking yet. Students will get to share their ideas when it is time to plan.
2. Have students open their notebooks up to the "Imagine" portion. Give each group a sample of their materials. Clarify that these are not part of their building materials, so they don't have to worry about damaging them. Encourage students to experiment with the materials as they imagine ideas.

Sample materials- give each group:

- 3 sheets of 8 ½" x 11" paper
- 3 pipe cleaners
- 6 in. of masking tape
- scissors
- 1 ruler
- 1 hole punch

3. Give students 5 min. to imagine ideas. Circulate among the students. If students are having trouble imagining ideas, ask them to think about the images of scaffolding systems they saw in class, or structures they've seen in real life. Ask:
 - What kinds of shapes did you see in those structures?
 - Were the structures wide? Short? Tall? Narrow?
 - Were the structures the same width the whole height?
 - Have you ever built something before, even out of different materials? In that past experience, what helps a structure be strong? Stable?
4. After 5 min., ask the students which step is next in the engineering design process. (*plan*) Set expectations for how students will interact- taking turns, speaking kindly, voting on ideas, etc. Emphasize that groups can combine ideas- they don't just have to choose one. Tell the groups to draw their ideas in their notebooks.
5. Give students 5 min. to collaborate and form a plan. Circulate during this time, asking students questions:
 - What do you think about _____'s idea?
 - Has everyone gotten a turn to share?
 - What have you seen in real life, or what past experience, makes you think your design will be successful?
6. After 5 min., check each group's design for approval. Retrieve the sample materials (leave the hole puncher, scissors, and ruler).
7. Ask students which step is next in the engineering design process. (*create*) Tell students that they will have 15 min. to create their scaffolding structures. Remind students that they can make changes to their design as they build, but that these changes should also be changed in their plan.
8. Give each group their building materials and set a timer for 15 min. During this time, students should record the process of creating their design in their notebooks, including any changes they've made to their designs. Circulate during this time, asking students questions:
 - How did you come up with this idea?
 - Does your design look like anything you've seen in real life?
 - What sort of changes have you made to your design so far? Why? Have you recorded this in your notebook?
 - Have you recorded what you've done so far in your notebook?
 - Why do you think your design will be successful?

9. After 15 min., test each group's design one at a time while the rest of the class watches. For each group:
- Have the group share their idea with the rest of the class and briefly explain how they came up with the design. Measure the height to make sure it meets the minimum requirement.
 - Make sure the design can balance on its own. If it can, that group can check off "stability" in their notebooks.
 - Lay the book representing the workers' mass on top of the design. Count up to 30. If the design fails before 30 seconds, the group will record the time in their notebooks.
 - If the design makes it to 30 seconds, place one "building material" in a cup on top of the book and count to 10. Continue until the design fails. The group should then record how many building materials their design supported.
 - Groups calculate the total mass in grams that their structures could support. They then record this and the height of their towers in a bar graph in the engineering notebook.
 - Groups also record the perimeter of the top of their design.
- Teacher Tip:**

For the sake of time, multiple groups can test at once as long as all of the books have the same mass.

In this case, give students a few minutes to walk around and look at other groups' designs before beginning the test.
10. Ask students which step is next in the engineering design process. (*improve*) Tell students that they will have 10 min. to improve their scaffolding structures. Remind students that they can make changes to their design as they build, but that these changes should also be changed in their plan.
11. Set a timer for 10 min. Circulate during this time, asking students questions:
- What was successful about your design in the first test? What failed in your design in the first test?
 - How are you planning to improve your design based on test results?
 - What sort of changes have you made to your design so far? Why?
 - Have you changed these in your plan as well?
 - Why do you think your improved design will be more successful than your first design?
12. After 10 min., test each group's design one at a time while the rest of the class watches. For each group:
- Have the group share their idea with the rest of the class and briefly explain how they improved the design. Measure the height to make sure it meets the minimum requirement.
 - Make sure the design can balance on its own. If it can, that group can check off "stability" in their notebooks.

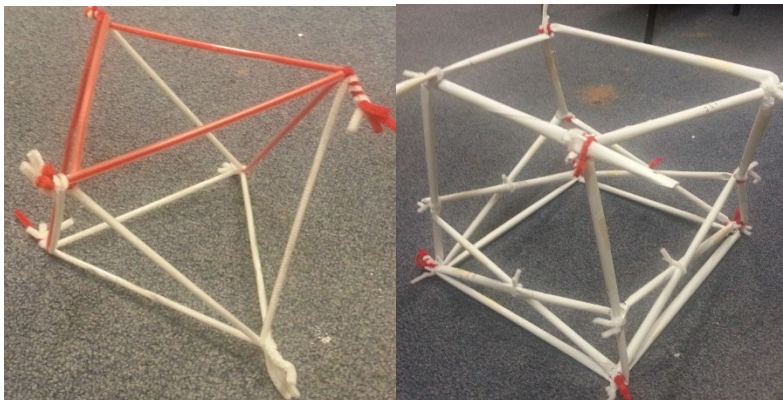
- Lay the book representing the workers' mass on top of the design. Count up to 30. If the design fails before 30 seconds, the group will record the time in their notebooks.
- Groups calculate the total mass in grams that their structures could support. They then record this and the height of their towers in a bar graph in the engineering notebook.
- Groups also record the perimeter of the top of their design.

13. If the design makes it to 30 seconds, place one "building material" in a cup on top of the book and count to 10. Continue until the design fails. The group should then record how many building materials their design supported.

Reflection (5 min.)

1. Ask the students:
 - Was your second design more successful than your first design? Why or why not?
 - What did different groups' designs have in common? Did any of these commonalities seem to contribute to the success of the designs?
 - How were different groups' designs unique? Did any of these differences seem to contribute to the success of the design?
 - How would you improve your team's design if you had more time?
2. Have students record their thoughts in the reflection portion of their notebooks.

The pictures below are example structures made from each set of materials. These are examples for the teacher only and should NOT be shown to students.



Extension Activity

The following resource provides an additional extension and reinforcement activity.

- “Building a Tower- an Engineering Design Challenge”
 - <http://www.cpalms.org/Public/PreviewResourceLesson/Preview/37741>







Design a Roller Coaster

Prep: 5 – 10 min.

Activity: 65 min.

Science Topic: Motion of Objects

Learning Objectives: Students will...

- Explore different ways objects move.
- Investigate the effect of applying various pushes and pulls on different objects.
- Use empirical evidence to explain the relationship between force, energy, and motion.

Vocabulary

- force
- gravity
- energy
- potential energy
- kinetic energy
- friction
- motion
- accelerate
- momentum

Overview

In this pre-activity, students explore the effects of various forces on the motion of an object. Students use the engineering design process to find a possible solution to the problem: Create a roller coaster which is safe and fun.

Students must collaborate with their peer(s) to design a model roller coaster which will meet their developmentally-appropriate criteria. Students will determine whether their structure has met the criteria, and whether their second prototype has improved in meeting this criteria.

Students work within materials and time constraints as they attempt to solve the problem. Students receive a set number of developmentally-appropriate building materials and create, test, and improve their designs. Students evaluate their designs to determine whether they have met the goal criteria.

Students share their design with their classmates and compare different designs to appreciate the creativity that goes into engineering.

Background

Review from previous activity: Force and gravity.

Energy is the capacity for doing work. It cannot be created or destroyed but, instead is converted from one form of energy to another. These conversions can be caused by an imbalance of forces acting on an object and can cause a change in **motion**, or how an object moves.

- **Potential energy** is stored energy. For example, a roller coaster car resting at the base of the first hill has balanced forces acting on it between gravity pulling it toward the center of the earth and the rails pushing back against the car. However, when the car is at the top of the first hill it gains potential energy to be pulled toward the ground due to gravity. The potential energy of an object will only change if the energy converts, decreasing the potential energy, or if additional work is applied to the object, creating additional potential energy.
- **Kinetic energy** is the energy an object possesses due to its motion. For example, when the roller coaster car goes down the first hill, gravity is acting on the car more than any other force. As a result, some of the potential energy converts into kinetic energy as gravity pulls it toward the center of the earth.

A force can cause a motion to **accelerate**, or speed up. Other forces can cause an object to slow down or even cease moving. Speed (or velocity) = distance/time.

Friction is a force that slows the motion of an object down. Friction is the conversion of energy to heat when surfaces move against one another in opposite directions. For example, friction is created on a roller coaster between the car and the track and the car and air molecules. This is why each successive hill must be shorter than the hill before it- energy is gradually converted into heat due to friction, leaving less kinetic energy to push the car to the top of each hill.

Momentum is the relationship between the mass of an object and its speed of motion, or velocity. Momentum = mass x velocity. So the greater the mass and/or speed of an object, the more momentum it has. Greater force is required to alter the motion of an object with greater momentum. For example, a heavy roller coaster car will need more force applied to it than a light car in order to accelerate, and one it has accelerated will need more force applied to it to slow down or stop.

Resources

For more information, please access the following resources:

- Kids Discover
“Spotlight: Force and Motion”
<http://www.kidsdiscover.com/spotlight/force-motion-kids/>

- <http://www.physics4kids.com/>

Pre-Requisite Knowledge

Students should have grade-appropriate comprehension of the following concepts:

Basic (students do not necessarily need to be able to do these independently)

- A basic understanding that gravity is the force that pulls objects toward the earth's surface
- A force is a push or a pull on an object that can change how the object is moving
- Energy is an object's capability to move
- Connecting counting and cardinality
- Either the ability to "count on" and "count back" or add and subtract
- Comparing greater than, less than, and equal to
- Motor skills to cut paper and use tape

Advanced

- An understanding of what gravity is and how it affects objects' motion
- An understanding of potential and kinetic energy
- How to measure with measuring tape to the nearest $\frac{1}{4}$ inch
- How to measure time in seconds
- How to present information in a bar graph
- Addition, subtraction, and division

Pre-Requisite Resources: The following resources provide activities for educators who have not yet covered pre-requisite science concepts in the classroom:

- See previous activity for: Force and gravity
- Energy
 - **Basic:** "Vibrations Make Sound"
 - This lesson explains energy and motion with sound vibrations.
 - <http://www.cpalms.org/Public/PreviewResourceUpload/Preview/12918>
 - **Advanced:** "Is It Energy?"
 - This lesson teaches students about energy through informational text.
 - <http://www.cpalms.org/Public/PreviewResourceLesson/Preview/39358>

Materials

For the Class:

- Engineering Design Process (on the board or on chart paper)
- Images of examples of roller coasters
- 3 rolls masking tape

For Each Group of Students

- 1 Timer
- 1 Glass marble
- 12 paper plates with deep lip (a marble should be able to roll against the edge of the plate without rolling off)
- 22 sheets of paper, 8 ½" x 11" - **tip: use recycled paper**
- 1 measuring tape
- Scissors
- Calculator

For Each Student

- Pencil
- Advanced engineering notebook

Introduction (15 min.)

1. Review what students learned in the scaffolding system activity about force and motion.
 - Extend the discussion to include momentum.
2. Lead students in a discussion about energy. Ask:
 - **What is energy?** (*The capacity of an object to move*)
 - **What are some different forms of energy?** (*Answers will vary and could include: sound vibrations, solar, potential, kinetic*)
 - **When have you seen a force act on an object, giving it energy to move?** (*Answers will vary. Examples: gravity causing structures to fall as in the last activity, throwing or kicking a ball, wind*)
 - **What is potential energy?** (*stored energy*)
 - **What is kinetic energy?** (*energy of motion*)

3. Explain to students that energy is never created or lost, simply converted into other forms of energy.
4. Explain to students that while some forces cause objects' motion to increase, other forces slow objects down. Ask:
 - **What do you know about friction?** (*Pause and take answers.*) Clarify: Friction is a force that converts energy to heat when objects rub together. This means that objects have less kinetic energy and slow down.
5. Review what students learned about engineers and the engineering design process in the previous activity. Explain to the students that they are going to be engineers again, but will have a different problem to solve for this activity.
 - **Problem:** An older theme park is not getting as many guests anymore. They need a new, exciting roller coaster to draw crowds in again.
 - **Goal:** Design a roller coaster that is safe and fun.
6. Ask the students: **“Now that we have our goal, where should we start in the engineering design process?”** (*We should ask questions to identify criteria and constraints as well as to explore any science and math content we will need to know to solve the problem.*)
7. Record students' questions on the board. Make sure the following questions end up on the board:
 - **What are the criteria for “fun?”**
 - **What are the criteria for “safe?”**
 - **Does the roller coaster need to be a certain length?**
 - **How fast does the roller coaster need to go?**
 - **How long will we have to create our designs?**
 - **What materials can we use?**
 - **What examples of real roller coasters are there?**
8. After students have finished brainstorming questions, answer each of them. Record criteria and constraints on the board or on chart paper. Students should record the criteria in the appropriate places in their notebooks.
 - **Fun:**
 - The roller coaster is fun if it has at least two turns or hills in it.
 - The roller coaster is fun if it is fast (see speed criteria).
 - **Safety:**
 - The roller coaster car (marble) must remain on the track the entire length of the roller coaster to be considered safe.
 - **Length:**
 - The roller coaster must extend from the seat of a chair to the floor.
 - **Speed:**

- The faster the roller coaster is, the more fun people will think it is. The theme park will want the fastest design which is still safe, so students will try to create the fastest design in the class.
 - The way to calculate speed is to divide the length of the roller coaster track by the amount of time the ride lasts for. Students will measure the length to the nearest $\frac{1}{4}$ " with a measuring tape and will measure time with a stop watch.
 - **Time:** (show the students each corresponding page in their notebooks)
 - Each student will have 5 min. to imagine ideas in their notebooks.
 - Teams will then collaborate for 5 min. to develop a plan.
 - Once the plan has been approved by the teacher, teams will have 15 min. to create their designs. Any changes to the designs should be reflected in the plan.
 - We will test the fun and safety of our designs.
 - Teams will then have 10 min. to improve their designs.
 - We will test the fun and safety of our improved designs.
 - **Materials:**
 - Students will receive 1 ft. of tape at a time, but will not be limited on how much total tape they can use.
 - Each group will receive 20 sheets of paper, 10 paper plates, scissors, a stopwatch, and measuring tape. A marble will represent the roller coaster car.
 - To make it more challenging, students cannot tape their coaster track to tables or chairs; they must create support structures themselves.
 - **Examples of roller coasters:**
 - Ask: **Have you ever been on or seen a roller coaster before? What was it like? What kinds of materials were they made out of?**
 - Show the students the example images of real roller coasters. Ask:
 - **How are the designs similar and different?** (*materials, loops, hill size, curves*)
 - **What different main features do you see?** (*Support beams, tracks, roller coaster car*)
 - **What are some different ways that these designs have been supported for stability?** (*Straight beams, diagonal beams, cross beams*) **Did you use any of these features to create your scaffolding system?**
 - Make sure students understand that their designs do not have to look like any of these images, but they can take inspiration from them if they like.
9. Show students an example of each type of material they will receive. Call on a few students to share ideas about each question.
- **How could we use these materials to create hills?**

- **How could we use these materials to create turns?**
- **How could we use these materials to create support beams to hold up our roller coaster?**

Activity (45 min.)

1. Have students remind you of the next step in the engineering design process. (*imagine*)
Explain that students should be imagining individually and not talking yet. Students will get to share their ideas when it is time to plan.
2. Have students open their notebooks up to the “Imagine” portion. Give each group a sample of their materials. Clarify that these are not part of their building materials, so they don’t have to worry about damaging them. Encourage students to experiment with the materials as they imagine ideas.

Sample materials- give each group:

 - 2 sheets of 8 ½” x 11” paper
 - 2 paper plates
 - 6 in. of masking tape
 - scissors
3. Give students 5 min. to imagine ideas. Circulate among the students. If students are having trouble imagining ideas, ask them to think about the images of roller coasters they saw in class or structures they’ve seen in real life. Ask:
 - What kinds of shapes did you see in those examples?
 - Were the roller coasters wide? Short? Tall? Narrow?
 - How could you use your materials to create the track?
 - What kind of supports were added to the roller coasters? How could you use your materials to create supports?
 - In the last activity, what helped a structure be strong? Stable?
4. After 5 min., ask the students which step is next in the engineering design process. (*plan*)
Set expectations for how students will interact- taking turns, speaking kindly, voting on ideas, etc. Emphasize that groups can combine ideas- they don’t just have to choose one. Tell the groups to draw their ideas in their notebooks.
5. Give students 5 min. to collaborate and form a plan. Circulate during this time, asking students questions:
 - What do you think about _____’s idea?
 - Has everyone gotten a turn to share?
 - What have you seen in real life, or what past experience, makes you think your design will be successful?
6. After 5 min., check each group’s design for approval. Retrieve the sample materials (leave the scissors).

7. Ask students which step is next in the engineering design process. (*create*) Tell students that they will have 15 min. to create their roller coasters. Remind students that they can make changes to their design as they build, but that these changes should also be changed in their plan.

8. Give each group their building materials and set a timer for 15 min. During this time, students should record the process of creating their design in their notebooks, including any changes they've made to their designs.

Circulate during this time, asking students questions:

- How did you come up with this idea?
- Does your design look like anything you've seen in real life?
- What sort of changes have you made to your design so far? Why? Have you recorded this in your notebook?
- Have you recorded what you've done so far in your notebook?
- Why do you think your design will be successful?

Teacher Tip:

Have extra paper and paper plates on hand to replace students' materials that get too damaged to keep using as they make changes to their design.

9. After 15 min., have groups measure the length of their coaster track and record it in their notebooks. Then, test each group's design one at a time while the rest of the class watches. For each group:

- Have the group share their idea with the rest of the class and briefly explain how they came up with the design.

10. After all groups have tested, determine whose coaster was the fastest. The rest of the teams will need to try and increase their speed to be faster than that group.

Teacher Tip:

For the sake of time, multiple groups can test at once.

In this case, give students a few minutes to walk around and look at other groups' designs before beginning the test.

11. Ask students which step is next in the engineering design process. (*improve*) Tell students that they will have 10 min. to improve their roller coasters. Remind students that they can make changes to their design as they build, but that these changes should also be changed in their plan.

12. Set a timer for 10 min. Circulate during this time, asking students questions:

- What was successful about your design in the first test? What failed in your design in the first test?
- How are you planning to improve your design based on test results?
- What sort of changes have you made to your design so far? Why?
- Have you changed these in your plan as well?

- Why do you think your improved design will be more successful than your first design?

13. After 10 min., test each group's design one at a time while the rest of the class watches.

For each group:

- Have the group share their improved design with the rest of the class and briefly explain how they came up with the design.
- Students check off whether the coaster track goes from the chair to the floor and then whether the track is safe- i.e. test with marble. If a group successfully meets both criteria, give them an extra challenge- i.e. measure the track length and make the track longer, put in a turn.

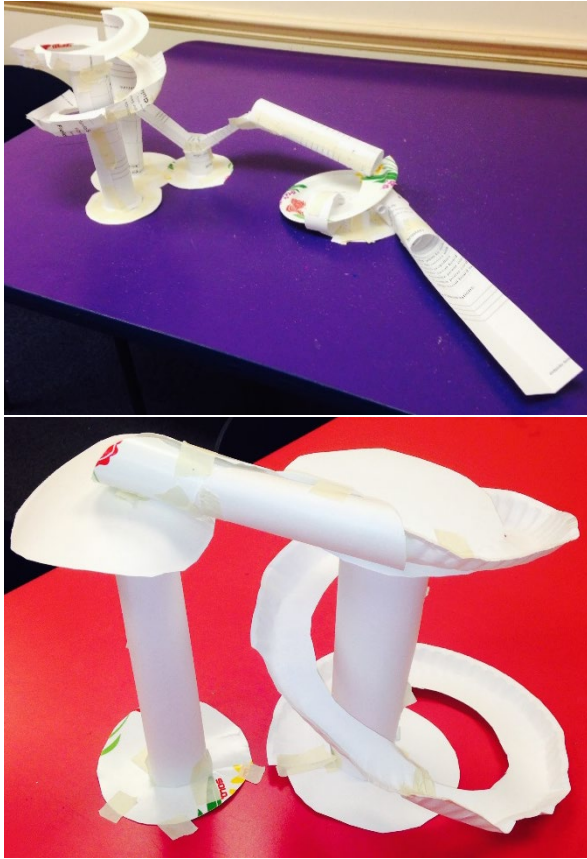
Reflection (5 min.)

1. Ask the students:

- Was your second design more successful than your first design? Why or why not?
- What did different groups' designs have in common? Did any of these commonalities seem to contribute to the success of the designs?
- How were different groups' designs unique? Did any of these differences seem to contribute to the success of the design?
- How would you improve your team's design if you had more time?

2. Have students record their thoughts the reflection portion of their notebooks.

The pictures below are example structures made from each set of materials. These are examples for the teacher only and should NOT be shown to students.



Extension Activities

The following resource provides an additional extension and reinforcement activity.

- “Use the Force! Racing Zucchini”
 - <http://www.cpalms.org/Public/PreviewResourceLesson/Preview/46823>





Design Play Dough

Prep: 5 – 10 min.

Activity: 65 min.

Science Topic: Changes in Matter

Learning Objectives: Students will...

- Explore observable properties of materials: Shape, color, temperature, texture, state of matter, harness, and volume.
- Investigate effects of altering materials on observable properties.
- Use empirical evidence to explain how observable properties change when materials are altered.

Vocabulary

- matter
- states of matter
- solid
- liquid
- gas
- properties
- volume
- quality
- texture

Overview

In this pre-activity, students explore the effects of altering materials on observable properties. Students use the engineering design process to find a possible solution to the problem: Create high quality play dough.

Students must collaborate with their peer(s) to design play dough which will meet their developmentally-appropriate criteria. Students will determine whether their design has met the criteria, and whether their second design has improved in meeting this criteria.

Students work within materials and time constraints as they attempt to solve the problem. Students receive a set number of developmentally-appropriate materials and create, test, and improve their designs. Students evaluate their designs to determine whether they have met the goal criteria.

Students share their design with their classmates and compare different designs to appreciate the creativity that goes into engineering.

Background

Matter is anything that has mass (amount of stuff in an object) and takes up space. Volume is the amount of space which matter fills.

We can sort matter by **properties**, which are things we can observe about matter with our five senses. We can see properties such as color and shape. We can hear properties such as fizzing. We can taste and smell some chemical properties of matter. We can touch matter to feel properties like **texture** (how something feels, soft, rough, etc.) and temperature.

Matter exists in five distinct forms called **states of matter**: Solid, liquid, gas, plasma, and Bose-Einstein condensates (BEC). Matter is made up of microscopic (too small to see with the naked human eye) particles, which behave differently in each state of matter, according to Newton's laws. In elementary school, students are introduced to the three most commonly observed states of matter.

- **Solid:** Particles are tightly packed, arranged in a regular to a semi-regular pattern. Particles can vibrate, but do not move from place to place. Because of this, a solid has a fixed shape and a fixed volume.
- **Liquid:** Particles are close together with no regular pattern of arrangement. Particles can vibrate, move about, and slide past one another. Because of this, liquid has a fixed volume but does not have a fixed shape. When placed in a container, a liquid will take the shape of that container, but will only fill the container up to its own volume.
- **Gas:** Particles are well separated with no regular pattern of arrangement. Particles vibrate and move about at high speeds. Because of this, gas has no fixed shape or volume. Gas assumes both the shape and volume of its container.

Some substances cannot truly be classified as a single state of matter. These substances exhibit 1 or more properties from multiple states of matter. Play Dough is such a substance. The particles are packed more closely together than in traditional liquids, but not quite as densely as a solid. Because of this, play dough will take the shape of a container, but can also maintain its own shape for a short amount of time.

Resources

For more information, please access the following resources:

- Chem4Kids
"Matter is the Stuff Around You"
http://www.chem4kids.com/files/matter_intro.html

Pre-Requisite Knowledge

Students should have grade-appropriate comprehension of the following concepts:

Basic (students do not necessarily need to be able to do these independently)

- Define and identify states of matter: Solid and liquid.
- Make observations about the properties of materials such as shape, color, temperature, and texture.
- Recognize that the shape of materials can be changed by tearing, crumpling, smashing, and rolling.
- Either the ability to “count on” and “count back” or add and subtract
- Comparing greater than, less than, and equal to
- The ability to measure volumes of liquids and solids using a tablespoon

Advanced

- Explain states of matter: Solid, liquid, and gas
- Classify material’s state of matter according to observable properties
- Measure the volume of liquid and solid materials
- Compare materials according to observable properties
- Addition, subtraction, and multiplication
- Fractions
- The ability to measure volumes of liquids and solids using a tablespoon

Pre-Requisite Resources: The following resources provide activities for educators who have not yet covered pre-requisite science concepts in the classroom:

- States of Matter (three-part lesson)
 - Part 1: “Super Solids”
<http://www.cpalms.org/Public/PreviewResourceLesson/Preview/46557>
 - Part 2: “Lovely Liquids”
<http://www.cpalms.org/Public/PreviewResourceLesson/Preview/46565>
 - Part 3: “Glorious Gases”
<http://www.cpalms.org/Public/PreviewResourceLesson/Preview/46567>

Materials

For the Class:

- Store-bought play dough OR home-made high quality play dough (see prep)
- Low-quality play dough (see prep)
- Chart paper or whiteboard
- Sink with running water
- Pack of food coloring (at least yellow, red, and blue)
- Optional: glitter, microwave
- Engineering Design Process (on the board or on chart paper)

For Each Group of Students

- 1 cup flour
- 1 cup salt (fine table salt, not rock salt)
- 1 cup of vegetable oil
- 1 tbsp. cream of tartar
- 1 tablespoon measuring spoon
- ½ tablespoon measuring spoon
- One wooden craft sticks
- One plastic spoon
- 3 cups, 8 oz.
- Plastic or Styrofoam bowl (can use paper, but it will get soggy)

For Each Student

- Pencil
- Advanced engineering notebook

Prep

- Create a “quality” chart on chart paper or on the board. This is where students will create a rubric to score the quality of their play dough.

Play Dough Quality		
High Quality 3	Medium Quality 2	Low Quality 1

- Create a batch of low-quality play dough the same day of the lesson.
 - Mix 2 cups of flour and 1 cup of water for 30 sec.
 - Add $\frac{1}{4}$ cup of salt and stir for 30 sec. or until the mixture is too thick to stir.
 - Remove the mixture from the bowl and knead with hands for 30 sec. The play dough should be sticky and grainy.
 - Humidity levels will affect the consistency of the play dough. Add more water and salt as needed until the mixture is both sticky and grainy.
- If you do not have store-bought play dough, create a batch of high-quality play dough the same day of the lesson.
 - Gradually add $\frac{1}{4}$ cup of salt to $\frac{3}{4}$ of water, stirring vigorously\ for 1 min. Stir for additional time if necessary until salt is completely dissolved. Mix in 3 drops of food coloring and stir for 30 sec. or until evenly mixed.
 - In a separate large mixing bowl, mix 2 cups of flour and 2 tbs. of cream of tartar. Stir for 10 sec.
 - Add the salt/water mixture and 2 tbs. of vegetable oil to the flour/tartar mixture. Stir for 30 sec. or until the mixture is too thick to stir.
 - Remove the mixture from the bowl and knead on a flat surface for 30 sec. or until it reaches a play dough consistency.
 - Humidity levels will affect the consistency of the play dough. If it comes out too sticky, gradually add small amounts of flour until a play dough consistency is achieved. If it comes out too dry, gradually add small amounts of water.

- When it is time for students to create, set up a materials “store” on a side table where students can come to retrieve the materials of their choosing.

Introduction (15 min.)

1. Review what students learned in class about matter and observable properties.
2. Lead students in a discussion about energy. Ask:
 - **How do we know if a material is solid, liquid, or gas?** (*Whether it has a definite shape and volume or not*)
 - **What are some examples of each state of matter?** (*Answers will vary*)
 - **When have you seen something change from one state of matter to another?** (*Answers will vary. Examples: water evaporating, water freezing, mixing ingredients when baking*)
 - **Have you ever seen something that had properties of a liquid and a solid??** (*Answers will vary, but may include silly putty, Oobleck, play dough, Jell-O.*)
3. Review what students learned about engineers and the engineering design process in the previous activities. Explain to the students that they are going to be engineers again, but will have a different problem to solve for this activity.
 - **Problem:** A play dough making company lost their recipe and can’t make play dough! They need a new recipe to create high-quality play dough.
 - **Goal:** Create a recipe which will make high-quality play dough.
4. Ask the students: **“Now that we have our goal, where should we start in the engineering design process?”** (*We should ask questions to identify criteria and constraints as well as to explore any science and math content we will need to know to solve the problem.*)
5. Record students’ questions on the board. Make sure the following questions end up on the board:
 - **How will we determine the quality of our play dough?**
 - **What is a recipe?**
 - **What materials can we use?**
 - **How much time will we have?**
6. After students have finished brainstorming questions, answer each of them. Record criteria and constraints on the board or on chart paper. Students should record the criteria in the appropriate places in their notebooks.
 - **Play Dough Quality**
 - Explain to students that “quality” is how “good” or “bad” something is. Ask students what they look for in “good” quality play dough.

- Give each group a small sample of the store-bought (or home-made high-quality) play dough. Ask students to share their observations about the properties of this play dough. Record this in the “Play Dough Quality” chart under “High-Quality.” Observations may include:
 1. Easy to shape
 2. Maintains shape
 3. Not sticking to hands/surfaces
 4. Soft
 5. Smooth
 6. Colorful
- Collect the high-quality play dough and give each group a small sample of low-quality play dough. Ask students to share their observations about the properties of this play dough. Record this in the “Play Dough Quality” chart under “Low-Quality.” Observations may include:
 1. Does not maintain shape (students may describe as “melts” or “droops”)
 2. Sticks to hands/surfaces
 3. Rough/ grainy
 4. Not colorful
- Explain to students that this is their rubric for grading the quality of their play dough. Once they have finished making their play dough, they will observe the texture and make a shape out of it.
- If their play dough contains all of the “high-quality” properties, their score is a 3. If their play dough contains all of the “low-quality” properties, their score is a 1. If their play dough contains properties from both the high and low-quality columns- i.e. grainy but not sticky- their score is a 2.
- Tell students that they will get a chance to improve their play dough recipe with a 2nd batch to try and increase their score.
- **What is a recipe?**
 - A recipe is a series of steps to follow when mixing materials to create something new.
 - Students will cut out the steps from the “Recipe Steps” document and glue them in order in their notebooks.
 - Students will then need to record the steps in their improved recipe so they can analyze why the second batch was improved or not.
- **What materials can we use?**
 - Each group will receive a mixing bowl and plastic spoon for mixing ingredients, and a tablespoon and a wooden craft stick for measuring. Model how to scoop the material with the tablespoon and even the top by scraping the side of the craft stick along the top to remove excess material.
 - Each group will also receive a ½ tbsp. Ingredients will be on a materials table. Students do not have to use all of the different types of materials, but they can if they want. Students will choose up to a maximum amount of each

material they would like to use. Maximum amounts of each: Flour 16 tbsp., salt 16 tbsp., water 16 tbsp., vegetable oil 16 tbsp., cream of tartar 1 tbsp., food coloring 3 drops per color. Groups will determine what fraction of their recipe is each material.

- **How much time will we have?**

- Each student will have 5 min. to imagine ideas as a group.
- Teams will then collaborate for 5 min. to develop a plan.
- Once the plan has been approved by the teacher, teams can begin creating play dough. Unlike in the last activities, students can test and improve as they go, as many times as they can, in 25 min. However, each time they finish making a batch they must score, evaluate, and then begin a new, improved batch.
- After 25 min. we will share our final play dough and explain the improvements we made throughout.

Activity (45 min.)

1. Have students remind you of the next step in the engineering design process. (*imagine*) Explain that students will be imagining as a group for this activity.
2. Have students open their notebooks up to the “Imagine” portion. Give each group a sample of their materials. Clarify that these are not part of their building materials, so they don’t have to worry about damaging them.
 - Have students touch and look at each ingredient and observe the properties of each, but don’t mix yet.
 - Ask students to look at the scoring rubric and discuss with their groups which ingredient they think contributes to which property of play dough.
 - After a few min., have students discuss as a whole group which ingredients may contribute which property to the play dough and why. (*i.e. salt made the low-quality grainy because it feels grainy, flour made the high-quality soft and smooth because it feels like that, water may have made the low-quality sticky because it is wet*)
3. After 5 min., ask the students which step is next in the engineering design process. (*plan*) Set expectations for how students will interact- taking turns, speaking kindly, voting on ideas, etc. Emphasize that groups can combine ideas- they don’t just have to choose one. Tell the groups to draw their ideas in their notebooks.
4. Give students 5 min. to collaborate and form a plan (*i.e. glue cut-out recipe steps in their notebooks*). Students may experiment with mixing small amounts of their sample

Sample Materials- give each group:

- 1 tbsp. of each flour, salt, water, and vegetable oil
- 1 tsp. of cream of tartar
- 1 bowl
- 1 plastic spoon

ingredients from the “imagine” portion. Circulate during this time, asking students questions:

- What do you think about _____’s idea?
- Has everyone gotten a turn to share?
- What have you seen in real life, or what past experience, makes you think your design will be successful?

Teacher Tip:

If students are allowed to microwave, the teacher should facilitate microwaving water in a microwave-safe container for 30 sec. The teacher should check that the water is warm, but not too hot to touch.

Students retrieve the materials of their choosing up to the maximum amount from a “store.”

6. After 5 min., check each group’s design for approval. Retrieve the sample materials (leave the bowls and measuring spoons).
7. Ask students which step is next in the engineering design process. (*create*) Tell students that they will have 15 min. to create their play dough. Remind students that they can make changes to their design as they go, but that these changes should also be changed in their plan.
8. Give each group their building materials and set a timer for 25 min. Remind students to clean off their tablespoons between ingredients. During this time, students should record the process of creating their design in their notebooks, including any changes they’ve made to their designs. Circulate during this time, asking students questions:

- How did you come up with this idea?
- Does your design look like anything you’ve seen in real life?
- What sort of changes have you made to your design so far? Why? Have you recorded this in your notebook?
- Have you recorded what you’ve done so far in your notebook?
- Why do you think your design will be successful?

9. Make sure groups are testing as they finish a batch, recording results, evaluating, and then improving by starting over with a new batch. Make sure students keep each batch to compare it to the new batch to see if it has improved in quality.

10. After 25 min., have each group share their design and recipe. For each group:
 - Have the group share their improved design with the rest of the class and briefly explain how they came up with the recipe.
 - Have groups explain any improvements they made from their original recipe and why.

Reflection (5 min.)

1. Ask the students:
 - Was your final design more successful than your first design? Why or why not?
 - What did different groups' designs have in common? Did any of these commonalities seem to contribute to the success of the designs?
 - How were different groups' designs unique? Did any of these differences seem to contribute to the success of the design?
 - How would you improve your team's design if you had more time?
2. Have students record their thoughts the reflection portion of their notebooks.

Extension Activities

- Have students switch recipes and attempt to follow another group's recipe.
- Groups then have to improve their written recipes based on feedback from the other group.

Water Runoff Reduction

Prep: 5 – 10 min.

Activity: 65 min.

Science Topic: Earth and Space

Learning Objectives: Students will...

- Explore how the spread of urban pollution is affected by natural weather phenomenon, such as precipitation, weathering, and erosion.
- Investigate methods of reducing water runoff pollution in an urban landscape.
- Use empirical evidence to explain how different materials are effective or ineffective in reducing water runoff.

Vocabulary

- pollution
- urban
- infiltration
- precipitation
- condensation
- evaporation
- weathering
- erosion

Overview

In this pre-activity, students explore the effects of natural weather on the spread of urban pollution. Students use the engineering design process to find a possible solution to the problem: Prevent the spread of pollution into a river by reducing water runoff in an urban landscape.

Students must collaborate with their peer(s) to design a runoff reduction system which will meet their developmentally-appropriate criteria. Students will determine whether their system has met the criteria, and whether their second prototype has improved in meeting this criteria.

Students work within materials and time constraints as they attempt to solve the problem. Students receive a set number of developmentally-appropriate building materials and create, test, and improve their designs. Students evaluate their designs to determine whether they have met the goal criteria.

Students share their design with their classmates and compare different designs to appreciate the creativity that goes into engineering.

Background

All life on Earth requires water in order to survive. Different living things receive water in different ways. Plants absorb water from underneath the Earth's surface. Animals either drink water directly or ingest it through food.

Water on Earth is constantly changing and in motion. The water cycle describes the continuous movement on water on Earth, and the changes in states of matter it transitions through during this cycle.

The water cycle actually begins with the sun. The sun provides energy and heat, which causes water to move and transition between states.

- **Infiltration:** Water exists on the Earth's surface in its liquid form, contained in rivers, lakes, and oceans. Water also exists on the Earth's surface in solid form as snow and ice. As the snow and ice is heated, some melts into liquid. Some of the liquid water is absorbed through the Earth's surface. Some of this infiltrated water is absorbed through plant roots. Some is stored underground in aquifers.
- **Evaporation:** As liquid water on the Earth's surface is heated from the sun's energy it evaporates into a gas called water vapor. Some snow and ice sublimates directly from solid ice to water vapor. As water vapor heats up from the sun, it rises into the Earth's atmosphere.
- **Condensation:** The Earth's atmosphere gets colder as it gets further away from the Earth's surface. As water vapor rises up into the atmosphere it begins to cool, and eventually condenses into liquid water and ice, which we see as clouds.
- **Precipitation:** As more and more water vapor cools it forms larger water and ice drops, which eventually become too heavy to stay in the atmosphere. Gravity pulls condensed water back to the earth in the form of rain, sleet, hail, and snow. The precipitation falls back to Earth's surface, and the water cycle begins again.

Weathering is the process by which rock is dissolved, worn away, or broken down into smaller pieces. Weather provides many processes by which this may happen. Wind, rain, and snow wear rock away over time.

Erosion is the process by which rocks and sediments are picked up and moved to a new location by rain, wind, snow, and gravity. **Urban pollution** can be transported through erosion to areas outside of cities, such as rivers, lakes, and oceans.

Resources

For more information, please access the following resources:

- The Water Cycle: <http://water.usgs.gov/edu/watercycle.html>

- Weathering and Erosion:
<http://www.onegeology.org/extra/kids/earthprocesses/weathering.html>

Pre-Requisite Knowledge

Students should have grade-appropriate comprehension of the following concepts:

Basic (students do not necessarily need to be able to do these independently)

- Understands that gravity pulls objects toward the ground unless something holds them up.
- Can explain that water falls to the surface of the earth as rain.
- Understands that moving water can cause objects to move from one place to another.
- Can describe objects on the Earth's surface.
- Understands that some materials can absorb water, while other objects are water resistant.
- Comparing greater than, less than, and equal to
- Can count up or add onto and count down or take away, with whole numbers
- Can measure length in whole cm

Advanced

- Can describe the water cycle and how it relates to weather.
- Can explain weathering and erosion, and describe how they are different.
- Can describe human impacts on the environment.
- Can compare materials according to observable properties.
- Understands how to measure length in cm, to the nearest $\frac{1}{2}$ or $\frac{1}{10}$
- Can add and subtract decimals.

Pre-Requisite Resources: The following resources provide activities for educators who have not yet covered pre-requisite concepts in the classroom:

- Interactive Water Cycle: <http://water.usgs.gov/edu/watercycle-kids-adv.html>
- Weathering and Erosion:
<http://www.cpalms.org/Public/PreviewResourceUpload/Preview/30802>

Materials

For the Class:

- 6 oz. paper or plastic cup
- Sink with running water
- 1 roll of aluminum foil
- Craft felt, approx. 10 sheets (12" x 12")
- Approx. 50 rocks (1/2 – 1 in. diameter)
- Duct tape
- 3" x 5" sponges, approx. 20
- Approx. 50 wooden craft sticks
- Approx. 5 cups of sand
- 1 model urban landscape (see prep)
- Blue food coloring
- 1 tbsp. of each: glitter, vegetable oil, confetti
- Engineering Design Process (on the board or on chart paper)

For Each Group of Students

- Rectangular container (i.e. aluminum baking pan), at least 9" x 9", approx. between 2" – 4" tall
- sand (enough to fill half the rectangular container)
- 2-3 small objects, approx. 1" x 1" (i.e. wooden block, cup)
- Scissors
- Paper/plastic cup, 6 oz.

Teacher Tip:

Have students help you collect rocks and sand from outside ahead of time.

For Each Student

- Pencil
- Advanced engineering notebook

Prep

- Create a model landscape for each group in a rectangular container at least 9" x 9" and 2 – 4" tall. All of the containers must be the same size. Larger containers will be easier to use.
 - Fill half of the container with approx. 1 1/2 in. sand. The sand should slope gently down toward the empty side like a riverbank.
 - Cover the sand with a sheet of aluminum foil to create the "concrete ground." It is okay if a little sand is not under the foil. Tape the foil to the sides of the

container so it is securely in place. There should be at least $\frac{1}{2}$ in. between the foil and the top of the container.

- Cover 2-3 small objects, approx. 1" x 1", with aluminum foil. Use duct tape to attach these objects to the concrete ground. Make sure the objects are in the same spot in each model.
- Mark cm up one of the sides of the empty side of the container with a permanent black marker. This is how students will measure how deep the water is.
- Fill the empty side with water, enough to form a "river" which covers the sloping bank but does not cover most of the foil. It should be approx. 1" deep. Make sure all containers have exactly the same amount of water.
- For each group, and for the demonstration, fill a 6 oz. cup almost to the top with water. Make sure each cup has the same exact amount of water.



Water level
marked in cm

Introduction

1. Review what students learned in class about the water cycle, weathering, and erosion.
2. Review with the students what they learned in the previous activities about observable properties of materials, and how these properties affected the success of engineering designs.
3. Explain to students that places with a large population of people, like cities and towns, are called **urban** areas. Lead students in a discussion about pollution. Ask:
 - **What is pollution?** *(materials which are harmful to the environment)*
 - **Do you know of any types of pollution caused by people?** *(Answers will vary. Examples: Trash, litter, chemicals, oil, gas fumes, human waste)*
 - **How are these examples bad for the environment?** *(Answers will vary. Examples: Animals may eat or breathe them and be injured or die, plants may absorb them and die, then other animals wouldn't have enough food)*
 - **How could these negative impacts on the environment affect humans?** *(Answers will vary. Examples: We could also end up breathing/eating/drinking pollution or eating animals who are sick from the pollution.)*
4. Review what students learned about engineers and the engineering design process in the previous activities. Explain to the students that they are going to be engineers again, but will have a different problem to solve for this activity.
 - **Problem:** A city's pollution is spreading to a nearby river because of water runoff! They need to reduce water runoff in order to prevent the spread of pollution.
 - **Goal:** Create a system that will reduce water runoff in an urban landscape.
5. Ask the students: **"Now that we have our goal, where should we start in the engineering design process?"** *(We should ask questions to identify criteria and constraints as well as to explore any science and math content we will need to know to solve the problem.)*
6. Record students' questions on the board. Make sure the following questions end up on the board:
 - **What does the city look like?**
 - **What sort of pollution is happening in the city?**
 - **What is water runoff, and how does it spread pollution?**
 - **What materials can we use?**
 - **How much time will we have?**
 - **How will we measure our design's success?**

7. After students have finished brainstorming questions, answer each of them. Record criteria and constraints on the board or on chart paper. Students should record the criteria in the appropriate places in their notebooks.

- **City Model**

- Review what a model is with students. Show the students the model urban landscape. Explain what each part represents:
 1. The foil represents the ground in the city, which is concrete and asphalt. Ask: **What properties does the foil have in common with concrete and asphalt?** (*it is flat and smooth*)
 2. The three objects wrapped in foil represent buildings made of concrete, metal, and glass. Ask: **What properties does the foil have in common with concrete, metal, and glass?** (*It is flat and smooth*)
 3. The water represents a river. The ground slopes down toward the river.

- **Types of pollution**

- Explain that while in a real city there are many different types of pollution, we are only going to have four types of pollution in our model urban landscape. Show students each model pollution as you explain it:
 1. Vegetable Oil: The vegetable oil represents oil from cars.
 2. Glitter and confetti: The glitter and confetti represent trash like paper, food waste, Styrofoam, and plastic.
 3. Food coloring: The food coloring represents chemicals.
- Ask students where they would expect to find each type of pollution in a city. As students share ideas, add pollution to that area. Ideas may include:
 1. Oil- on the ground where cars would be driving on roads
 2. Trash- on the ground or around building where people throw it on the ground; in one area which could be a landfill
 3. Chemicals- around buildings which use cleaning products or which could be factories producing chemicals as by-products

- **Water Runoff and Pollution Spread**

- Ask students what they see happening to water from real rain once it hits the ground. Students should recall that the water moves across roads, sidewalks, and gutters downhill. Explain to students that this is water runoff.
- Show the students the cup filled with water. Make sure the water is the same amount students will receive during their test. Explain that you will simulate rain by pouring water onto the city. Ask students to predict what will happen to the water when it hits the surface.
- Pour water on the city, being sure to add water to all of the areas, for about 15 sec.
- Ask:

1. **What happened to the rainwater when it hit the surface of our model city?** *(The water was not absorbed by the foil. Gravity pulled it down into the model river. It may have flooded the city.)*
2. **How is this similar to what you have seen happen when it rains on concrete in real life?** *(The concrete, like the foil, does not absorb water. Gravity pulls the water downhill)*
3. **How did this water runoff affect the pollution?** *(Moving water moved the pollution into the river.)*
4. **How could the pollution in the river affect the environment and the people?** *(Plants and animals could get sick or die, people could drink the water and get sick)*

- **Materials**

- Each group will receive a model urban landscape, just like the one in the demonstration. Each group will receive scissors, which will be a tool they can use to manipulate their materials. Each group will also receive a cup, which will have the same amount of water in it as all the other groups, filled almost to the top. Students will pour the water from the cup onto the city to simulate rain.

- Groups will have a budget. The instructor should set the budget and assign a dollar amount for each material. Adjust dollar/cents to match the math your students are learning (i.e. decimals vs. whole numbers). Students should be able to purchase enough materials to be creative, but not so much that the challenge is too easy. Students will be able to choose to buy from the following types of materials:
 - Aluminum foil (sell per sq. in.)
 - Felt (sell per sq. in.)
 - Rocks (sell per rock)
 - Duct tape (sell per in.)
 - Sponges, 3" x 5" (sell per sponge)
 - Wooden craft sticks (sell per craft stick)
 - Sand (sell per tbsp.)

Sample budget: \$10

- Foil: \$0.50 per 1 in.²
- Felt: \$0.50 per 1 in.²
- Rocks: \$1 per rock
- Tape: \$0.50 per in.
- Sponge: \$3.00 per sponge
- Craft Sticks: \$0.50 per stick
- Sand: \$0.50 per tbsp.

- **Time** (show the students each corresponding page in their notebooks)
 - Each student will have 5 min. to imagine ideas in their notebooks.
 - Teams will then collaborate for 5 min. to develop a plan.
 - Once the plan has been approved by the teacher, teams will have 15 min. to create their designs. Any changes to the designs should be reflected in the plan.
 - We will test our designs.

- Teams will then have 10 min. to improve their designs.
- We will test our improved designs.
- **Design Success**
 - The students' models will not have pollution added to them. The students will measure the increase in the river's water volume to determine how much runoff they prevented.
 - For the test, each group will receive a cup of water (make sure the groups' cups have the same amount of water you used in the demo).
 - Point out the cm markings on the urban landscape model you used in the demo. Point out the cm the lake was at before you added water. Point out where it is now. With your students, subtract the original amount of water from the current amount to find the difference. For example:
 1. **Before it rained, there were 3 cm of water in the model lake.**
 2. **After it rained, there were 6 cm of water in the model lake.**
 3. **$6 - 3 = 3$ cm. So, 3 cm of water were added to our lake due to water runoff when it rained.**
 - Students' goal is to reduce the amount of water runoff into their groups' model lake. So, in the example above students would want less than 3 cm of water added to the model lake after it "rained." Have students record the exact cm they want to be less than in their journals.

Measuring:

Use cm to the nearest $\frac{1}{2}$ cm, or $\frac{1}{10}$ cm, depending on what your students have learned about measurement in math.

Students will graph the amount of water runoff in each test.

Activity

1. Have students remind you of the next step in the engineering design process. (*imagine*) Explain that students should be imagining individually and not talking yet. Students will get to share their ideas when it is time to plan.
2. Have students open their notebooks up to the "Imagine" portion. Give each group a sample of their materials. Clarify that these are not part of their building materials, so they don't have to worry about damaging them. Encourage students to feel the materials to explore their properties as they imagine ideas.

3. Give students 5 min. to imagine ideas. Circulate among the students. If students are having trouble imagining ideas, ask them to think about the demonstration of water runoff. Ask:

- Why did all of the water in the cup end up in the model lake?
- Was the water flow direction altered by anything in the model city?
- Think about everyday objects that are meant to keep liquids from spilling. What are they made of? What do they look like? (i.e. cups, trays, bowls)
- Think about everyday objects that are meant to clean up liquid spills. What materials are they made of? What are the properties of these materials which help the objects clean up liquid?
- How could you use your materials to stop some of the water from ending up in the model lake?

Sample materials- give each group:

- Aluminum foil, approx. 1" x 1"
- Craft felt, approx. 1" x 1"
- 1 rock (1/2 – 1 in. diameter)
- Small piece of duct tape
- 1" x 1" sponges
- 1 wooden craft stick
- A Ziploc bag containing a tbsp. of sand (tape shut so students do not open)

4. After 5 min., ask the students which step is next in the engineering design process. (*plan*) Set expectations for how students will interact- taking turns, speaking kindly, voting on ideas, etc. Emphasize that groups can combine ideas- they don't just have to choose one. Tell the groups to draw their ideas in their notebooks.
5. Give students 5 min. to collaborate and form a plan. Groups need to calculate their budget during the planning step. Circulate during this time, asking students questions:
- What do you think about _____'s idea?
 - Has everyone gotten a turn to share?
 - What have you seen in real life, or what past experience, makes you think your design will be successful?
6. After 5 min., check each group's design for approval. Retrieve the sample materials.
7. Ask students which step is next in the engineering design process. (*create*) Tell students that they will have 15 min. to create their runoff reduction systems. Remind students that they can make changes to their design as they build, but that these changes should also be changed in their plan.
8. Give each group their model urban landscapes and building materials and set a timer for 15 min. During this time, students should record the process of creating their design in their

notebooks, including any changes they've made to their designs. Circulate during this time, asking students questions:

- How did you come up with this idea?
- Does your design look like anything you've seen in real life?
- What sort of changes have you made to your design so far? Why? Have you recorded this in your notebook?
- Have you recorded what you've done so far in your notebook?
- Why do you think your design will be successful?

Teacher Tip:

Set building materials out on a table to set up a "materials store" where students can retrieve the materials they wish to purchase.

9. After 15 min., have groups stop building. Then, test each group's design one at a time while the rest of the class watches. For each group:

- Have the group share their idea with the rest of the class and briefly explain how they came up with the design.
- Have one member of the group gradually pour their cup of water over the model urban landscape to simulate rain. Make sure water is added over all parts of the landscape.
- After no more water is running off into the model lake, have students record the new lake height.
- Have groups check off whether or not their water runoff was reduced.

Teacher Tip:

For the sake of time, multiple groups can test at once.

In this case, give students a few minutes to walk around and look at other groups' designs before beginning the test.

10. Ask students which step is next in the engineering design process. (*improve*) Tell students that they will have 10 min. to improve their designs. Remind students that they can make changes to their design as they build, but that these changes should also be changed in their plan.

Measuring:

Use cm to the nearest 1/2 cm, or 1/10 cm, depending on what your students have learned about measurement in math.

11. Use the cups to remove water from the models until the model lake is back to its original height. All students to replace materials damaged by water.

12. Set a timer for 10 min. Circulate during this time, asking students questions:

- What was successful about your design in the first test? What failed in your design in the first test?

Teacher Tip:

Allow students to spend any leftover money in their budgets for additional materials.

Give additional money to their budgets for them to spend to improve if you think it is necessary.

- How are you planning to improve your design based on test results?
- What sort of changes have you made to your design so far? Why?
- Have you changed these in your plan as well?
- Why do you think your improved design will be more successful than your first design?

13. After 10 min., test each group's design one at a time while the rest of the class watches. For each group:

- Have the group share the changes they made to try and improve their design.
- Have one member of the group gradually pour their cup of water over the model urban landscape to simulate rain. Make sure water is added over all parts of the landscape.
- After no more water is running off into the model lake, have students record the new lake height.
- Have groups check off whether or not their water runoff was reduced.

Reflection

1. Ask the students:

- Was your second design more successful than your first design? Why or why not?
- What did different groups' designs have in common? Did any of these commonalities seem to contribute to the success of the designs?
- How were different groups' designs unique? Did any of these differences seem to contribute to the success of the design?
- How would you improve your team's design if you had more time?

2. Have students record their thoughts in the reflection portion of their notebooks.

Extension Activities

The following resource provides an additional extension and reinforcement activity.

- "The Perils of a Plant: Watering Can - An Engineering Design Challenge"
 - <http://www.cpalms.org/Public/PreviewResourceLesson/Preview/37027>

Design a Zip Line

Prep: 5 – 10 min.

Activity: 65 min.

Science Topic: Nature of Science

Learning Objectives: Students will...

- Raise questions about the natural world.
- Investigate inquiries in teams through an engineering design challenge.
- Use empirical evidence to form explanations.

Vocabulary

- Engineering Design Process
- Scientific Method
- Empirical evidence
- Innovation
- Analyze
- Evaluate

Overview

In this pre-activity, students explore how scientific reasoning is used during the Engineering Design Process. Students use the engineering design process to find a possible solution to the problem: Create a zip line which will deliver a package to a destination.

Students must collaborate with their peer(s) to design a model zip line which will meet their developmentally-appropriate criteria. Students will determine whether their structure has met the criteria, and whether their second prototype has improved in meeting this criteria.

Students work within materials and time constraints as they attempt to solve the problem. Students receive a set number of developmentally-appropriate building materials and create, test, and improve their designs. Students evaluate their designs to determine whether they have met the goal criteria.

Students share their design with their classmates and compare different designs to appreciate the creativity that goes into engineering.

Background

Review content from previous activities about force and motion.

Review content in front section of binder about the Scientific Method and the Engineering Design Process.

Resources

See resources in front section of binder about the Scientific Method and the Engineering Design Process.

Pre-Requisite Knowledge

Students should have grade-appropriate comprehension of the following concepts:

- See previous activities: Scaffolding System and Roller Coaster
 - Keep written and/or pictorial records of observations
 - Differentiate between opinions and facts
 - Justify explanations verbally and/or on paper with scientific observations

Pre-Requisite Resources: The following resources provide activities for educators who have not yet covered pre-requisite concepts in the classroom:

- Please see front section about the Scientific Method and the Engineering Design Process.

Materials

For the Class:

- Images of example zip lines
- Hole punch
- 3 oz. paper cup
- plastic cup
- large paper cup (same size as plastic, larger than 3 oz.)
- 8 ½" x 11" copy paper, approx. 50 sheets
- 3" x 5" index cards, approx. 50
- 1 skein of yarn
- 1 roll of wax paper
- 1 roll of aluminum foil
- 1 box of paper clips
- 3 rolls of masking tape
- Engineering Design Process (on the board or on chart paper)

For Each Group of Students

- Approx. 6 ft. of string
- Scissors
- 6 oz. Plastic cup
- Small object which fits easily in 6 oz. plastic cup; all groups must have the same object (i.e. hex nut, marble)
- 1 ruler

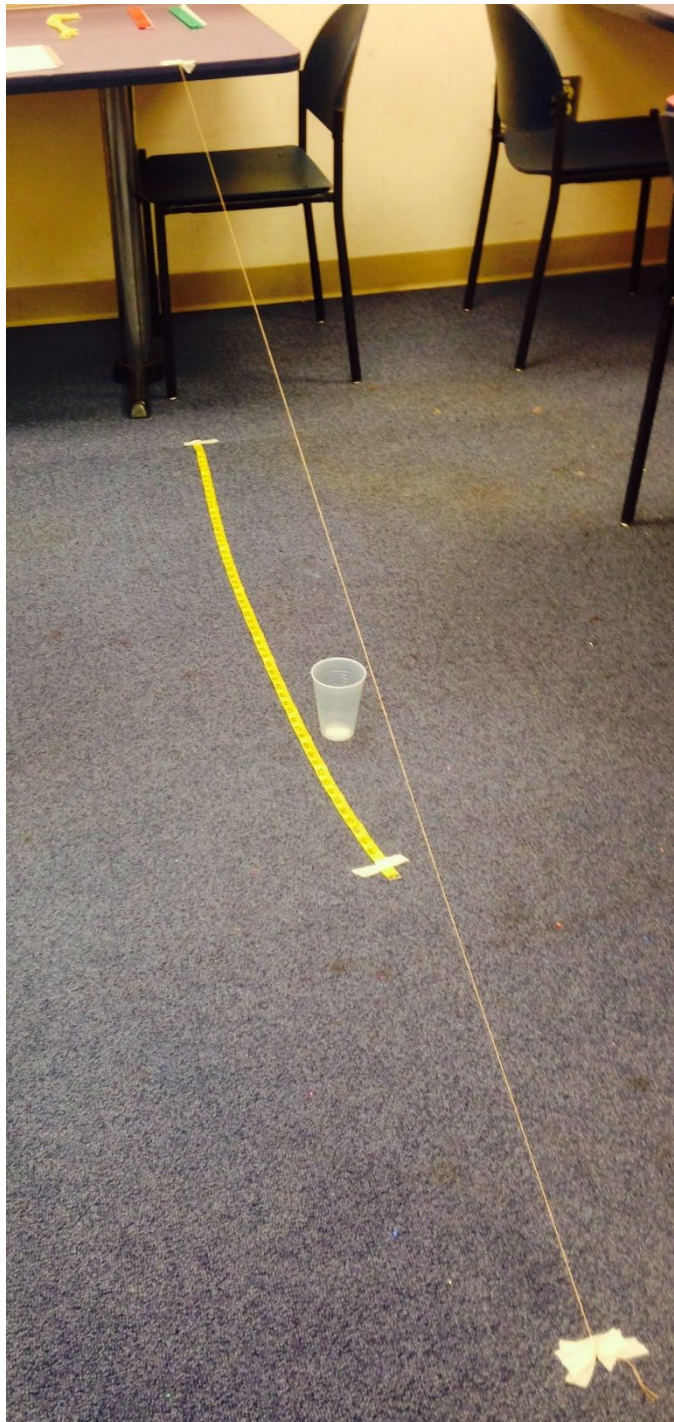
For Each Student

- Advanced Engineering Notebook
- Pencil

Prep

Prepare each group's zip line:

- Tape one side of the 6 ft. piece of string to the edge of the top of a desk or table. Make sure all groups' tables are the same height.
- Tape the other end of the string to the floor, so that it is at a diagonal angle and is taught.
- 4 ft. away from the table, and directly underneath the string, tape the 6 oz. plastic cup upright to the floor. This is the container the "payload" must land in.
- Make sure the string is not closer than 5 in. to the top of the cup. If it is, adjust the distance of the cup closer to the table as needed, and change the distance in the goal you give your students.



Introduction

1. Review with students what they learned about force and motion in previous activities.
2. Review with students what they have learned in class about the Scientific Method and what they have learned in previous activities about the Engineering Design Process.
3. Point out the differences between the two:
 - **In the Scientific Method, scientists investigate a question to find an answer.**
 - **There is no right or wrong answer in engineering. Engineering is “innovation”- the use of creativity to come up with a new idea. In engineering, you use your innovation to find one possible solution to a problem, but there are infinite possible solutions.**
4. Explain that while the processes are not the same, scientific reasoning is used during an engineering design challenge.
 - **During the “ask” stage of the Engineering Design Challenge, engineers will sometimes collaborate with scientists to perform experiments in order to gather scientific data. This data is called “empirical evidence”- information gathered through scientific experimentation.**
 - **The testing stages of the Engineering Design Process are set up like an experiment. Empirical evidence is gathered during the tests.**
 - **The data is “analyzed”- that is, engineers examine it for understanding and explanation.**
 - **The design is then “evaluated.” Based on the analysis of empirical evidence, did the design meet the goal criteria and how could it be improved?**
5. Explain to the students that they are going to be engineers who will be solving a problem using the engineering design process. Tell the students the problem and goal, and write the goal on the board:
 - **Problem:** A company on one side of a protected forest needs to transport its products to a town on the other side of the protected forest. The forest cannot be damaged, so building a pathway through the forest is not possible. The company needs engineers to design a container that can transport its goods using a zip line system to the town.
 - **Goal:** Design a container which can transport a company’s products using a zip line to a town on the other side of a protected forest.
6. Ask the students: **“Now that we have our goal, where should we start in the engineering design process?”** *(We should ask questions to identify criteria and constraints as well as to explore any science and math content we will need to know to solve the problem.)*

7. Record students' questions on the board. Make sure the following questions end up on the board:

- **What is a zip line?**
- **What are the products our container needs to transport?**
- **What is the distance our container needs to travel on the zip line?**
- **What materials can we use?**
- **How much time will we have to create our zip line containers?**

8. After students have finished brainstorming questions, answer each of them. Record criteria and constraints on the board or on chart paper. Students should record the criteria in the appropriate places in their notebooks.

- **Zip lines**

- A zip line is made up of a support cable, which is elevated on one side. A load is attached to the cable loosely enough to be able to move back and forth on the cable. Gravity pulls the load from the elevated side of the cable down to the other end.
- Zip lines are sometimes used for recreation. (show images)
- Zip lines are also used in areas like rainforests for the transportation of goods or people. These areas are either too difficult to build roads through, or people wish to avoid damaging the ecosystem. (show images)

- **Product**

- Show students one of the objects which will be their payload (i.e. hex nut). Explain that this represents the mass of the product the company needs to have transported.

- **Distance**

- Show students one of the zip lines. Point out the distance between the table and the 6 oz. plastic cup and explain that it is 4 ft. (or the distance you had to adjust it to during prep).
- Explain that the company is on the table, at one end of the zip line.
- Explain that the cup on the floor represents the town the product needs to be transported to. The cup is on the floor because the town cannot be moved.
- Additionally, the container must dump the payload into the cup- it cannot land on the floor.
- So, the container must **travel a distance of 4 ft. without dropping the payload onto the ground.**

Measuring:

Students will mark the distance in each test on a number line in their engineering notebook.

- **Materials**

- Show the students the materials they may choose from (see materials section at beginning of lesson plan). Explain that each group may choose 5 materials to build their container out of. Groups may also choose to add materials to the zip line itself if they wish.

Teacher Tip:

Adjust the number of materials students may choose as developmentally appropriate to make it more or less challenging.

- **Time**

- Each student will have 5 min. to imagine ideas in their notebooks.
- Teams will then collaborate for 5 min. to develop a plan.
- Once the plan has been approved by the teacher, teams will have 15 min. to create their designs. Any changes to the designs should be reflected in the plan.
- We will test the height, strength, and stability of our designs.
- Teams will then have 10 min. to improve their designs.
- We will test the height, strength, and stability of our improved designs.

Activity

9. Have students remind you of the next step in the engineering design process. (*imagine*) Explain that students should be imagining individually and not talking yet. Students will get to share their ideas when it is time to plan.
10. Have students open their notebooks up to the “Imagine” portion. Give each group one of each material. Clarify that these are not part of their building materials, so they don’t have to worry about damaging them. Clarify that students may NOT build yet, but they may touch the materials to consider their properties.
11. Give students 5 min. to imagine ideas. Circulate among the students. If students are having trouble imagining ideas, ask them to think about the images of zip line systems they saw in class, or structures they’ve seen in real life. Ask:
 - What did the connection to the zip line look like?
 - What forces have we learned about which affects objects’ motion?
 - What force did we learn about when designing roller coasters which slows motion down?
 - During this time, also set up a “materials store.”
12. After 5 min., ask the students which step is next in the engineering design process. (*plan*) Set expectations for how students will interact- taking turns, speaking kindly, voting on ideas, etc. Emphasize that groups can combine ideas- they don’t just have to choose one. Tell the groups to draw their ideas in their notebooks.

13. Give students 5 min. to collaborate and form a plan. Circulate during this time, asking students questions:
- What do you think about _____'s idea?
 - Has everyone gotten a turn to share?
 - What have you seen in real life, or what past experience, makes you think your design will be successful?
14. After 5 min., check each group's design for approval. Retrieve the sample materials.
15. Ask students which step is next in the engineering design process. (*create*) Tell students that they will have 15 min. to create their zip line containers. Remind students that they can make changes to their design as they build, but that these changes should also be changed in their plan.
16. Have each group retrieve 5 materials from the materials table and set a timer for 15 min. During this time, students should record the process of creating their design in their notebooks, including any changes they've made to their designs. Circulate during this time, asking students questions:
- How did you come up with this idea?
 - Does your design look like anything you've seen in real life?
 - What sort of changes have you made to your design so far? Why? Have you recorded this in your notebook?
 - Have you recorded what you've done so far in your notebook?
 - Why do you think your design will be successful?
17. After 15 min., test each group's design one at a time while the rest of the class watches. For each group:
- Have the group share their idea with the rest of the class and briefly explain how they came up with the design
 - Have one team member hold the container at the top of the zip line and countdown to release on "go."
 - If the payload drops onto the ground before the cup, have students measure the distance the container traveled before that happened and record it.
 - If the design makes it to the cup, students can check off "4 ft." in their notebooks.
 - Have students check off whether or not the payload lands in the cup.
18. Ask students which step is next in the engineering design process. (*improve*) Tell students that they will have 10 min. to improve their zip line containers. Remind students that they can make changes to their design as they build, but that these changes should also be changed in their plan.

19. Set a timer for 10 min. Circulate during this time, asking students questions:

- What was successful about your design in the first test? What failed in your design in the first test?
- How are you planning to improve your design based on test results?
- What sort of changes have you made to your design so far? Why?
- Have you changed these in your plan as well?
- Why do you think your improved design will be more successful than your first design?

Teacher Tip:

If a group successfully completes all criteria in the first test, see how many “payloads” (hex nuts) the design can successfully transport.

20. After 10 min., test each group’s design one at a time while the rest of the class watches. For each group:

- Have the group share their improvements with the rest of the class and briefly explain how they changed the design
- Have one team member hold the container at the top of the zip line and countdown to release on “go.”
- If the payload drops onto the ground before the cup, have students measure the distance the container traveled before that happened and record it.
- If the design makes it to the cup, students can check off “4 ft” in their notebooks.
- Have students check off whether or not the payload lands in the cup.

Reflection

1. Ask the students:

- Was your second design more successful than your first design? Why or why not?
- What did different groups’ designs have in common? Did any of these commonalities seem to contribute to the success of the designs?
- How were different groups’ designs unique? Did any of these differences seem to contribute to the success of the design?
- How would you improve your team’s design if you had more time?

2. Have students record their thoughts in the reflection portion of their notebooks.

Extension Activities

Please visit CPALMS resources for a multitude of Engineering Design Challenges which incorporate Florida standards:

<http://www.cpalms.org/Public/search/Resource>



This is a zip line used in a remote region of Columbia- it is the fastest transportation they have to other areas. They use the zip line for traveling and also to transport goods. This little girl uses the zip line to get to school.



This is the tallest zip line in South America, used for entertainment.



This is a zip line used to transport a camera through the Amazon Rainforest for scientific observation.

Design a Paper-Copter

Prep: 5 – 10 min.

Activity: 65 min.

Science Topic: Force and Motion

Learning Objectives: Students will...

- Explore how to create “paper-copters” that will descend to the ground slowly.
- Investigate how size, shape, and mass affect drag.
- Use empirical evidence to explain why a blade’s size and shape, and/or a helicopter’s mass, cause a “paper-copter” to drop to the ground at a different rate of time.

Vocabulary

- gravity
- force
- mass
- friction
- drag
- motion
- helicopter
- blade
- surface area
- perimeter
- shape (rectangle, triangle, circle)

Overview

In this pre-activity, students explore how gravity and air resistance act on a falling object. Students use the engineering design process to find a possible solution to the problem: Create a paper-copter which will use drag to descend to the ground as slowly as possible from a given height.

Students must collaborate with their peer(s) to design a model paper helicopter that will meet their developmentally-appropriate criteria. Students will use developmentally-appropriate measuring tools to determine whether their structure has met the criteria and whether their second prototype has improved in meeting these criteria.

Students work within materials and time constraints as they attempt to solve the problem. Students receive a set number of developmentally-appropriate building materials and create, test, and improve their designs. Students evaluate their designs to determine whether they have met the goal criteria.

Students share their designs with their classmates and compare different designs to appreciate the creativity that goes into engineering.

Background

Review from the previous activity: Force, gravity, mass, friction, and motion.

Drag is a force that acts opposite to the motion of any object. Drag is created when the surface of an object touches the surface of an object moving in a different direction. As the surfaces move against one another, the energy of motion is gradually converted into friction. This causes the moving object(s) to slow down.

Size and **shape** affect the amount of drag created. **Surface area** is the amount of space a 2-dimensional object takes up. Surface area is calculated by multiplying an object's length by its width, or by counting how many unit squares fill an object. Shapes that have a greater surface area create more drag. **Perimeter** is the distance around the entire edge of an object (calculated by adding all of the side lengths of a shape). Increasing a shape's perimeter increases its surface area.

Engineers need to consider drag when they are designing **helicopters**. Helicopters are a type of aircraft which moves through the air using spinning **blades**. These blades create drag as they spin and move against the air around them. This drag acts opposite to the force of gravity. By changing the speed of blade rotation, as well as how the helicopter blades are angled, the helicopter can move in any direction. (This is a very simplified explanation of how helicopters work. Please see the article below "How Stuff Works" for a detailed explanation.)

Note to Instructor: This activity is already structured very differently for advanced and basic students. Thus, there are less advanced and basic tips in the margin for this lesson.

Resources

For more information, please access the following resources:

- How Stuff Works
"How Helicopters Work"
<http://science.howstuffworks.com/transport/flight/modern/helicopter3.htm>
- NASA
"What is Drag?"
<https://www.grc.nasa.gov/www/k-12/airplane/drag1.html>

Pre-Requisite Knowledge

Students should have grade-appropriate comprehension of the following concepts:

Basic (students do not necessarily need to be able to do these independently)

- A basic understanding that gravity is the force that pulls objects toward the earth's surface
- A force is a push or a pull on an object that can change how the object is moving
- Energy is an object's capability to move
- Connecting counting and cardinality
- Either the ability to "count on" and "count back" or add and subtract
- Basic two-dimensional shapes
- Comparing greater than, less than, and equal to
- Motor skills to cut paper and use tape

Advanced

- How to measure with a ruler to the nearest inch
- An understanding of what gravity is and how objects can overcome it
- How to measure time in seconds
- An understanding of basic units of measurement for mass (grams)
- How to present information in a bar graph
- Addition, subtraction, and multiplying single or double-digit numbers by a single-digit number
- How to calculate surface area and perimeter for two-dimensional shapes

Pre-Requisite Resources: Please see the following pre-activities for educators who have not yet covered pre-requisite science concepts in the classroom:

- Design a Scaffolding System (p. 15)
- Design a Roller Coaster (p. 30)

Materials

For the Class:

- Engineering Design Process (on the board or on chart paper)
- “Paper Copter Test: Size” (page 91)
- “Paper Copter Test: Mass” (page 92)
- 3 small paper clips (same mass)
- 1 digital scale (or balance scale with gram weights)

For Each Group of 3 – 4 Students

- 1 sheet of copy paper and 1 cardstock; 1 extra of one
- scissors
- 2 ft. of Scotch tape
- 5 small paper clips (same mass)
- ruler marked in inches or cm (teacher’s preference)
- Optional: paper copter template
- Optional: Markers/crayons to decorate paper-copters

For Each Student

- pencil
- advanced engineering notebook

Prep

- Paper Copter Shape Test
 - Print the three paper copter shape test templates out on copy paper:
 - “Paper Copter Shape Test: Circle”
 - “Paper Copter Shape Test: Square”
 - “Paper Copter Shape Test: Triangle”
 - Cut out the paper copter body and blade shapes on all three templates. **Be sure to only cut the solid lines.**
 - Fold on all three paper copter bodies where indicated by dotted lines.
 - Fold one blade forward and the other back. Crease.
 - Fold both sides back on the base. Fold the bottom of the base back at the top where you see the two dotted lines.
 - Secure the folded base with a small paper clip on the bottom of the base.



Make sure each copter body has a paper clip with the same

mass as the others. If the paper clips are not the same mass, it will affect the outcome of the test.

- Attach the shapes to the blades by taping one shape to the top of each blade. Make sure each paper copter body has two of the same shapes so you have one copter with square blades, one with triangle blades, and one with circle blades.



- Test the paper copter shape templates ahead of time. If the original template blades are not attached properly to the shape, they will flap and affect the outcome of the tests. Secure with more tape as needed.
- Paper Copter Size Test
 - Print the paper copter size test template out on copy paper:
 - Cut each template out and follow the directions in the Basic prep instructions for the paper copter body (NOT the blade shapes).
- Paper Copter Mass Test
 - Print the paper copter mass test template out on copy paper:
 - Cut each template out and follow the directions in the Basic prep instructions for the paper copter body (NOT the blade shapes). However, instead of putting 1 paper clip on each, place no paper clips on the light body, and 3 paper clips on the heavy body.
- Optional- print one "Paper Copter Test: Size" for each group on copy paper. Groups can choose which template size they want to use for their base copter.

Introduction (15 min.)

- I. Review with students what they have learned about force and motion. Ask:
 - **What is a force?** (*A force is a push or a pull that may change the motion of an object.*)
 - **What is the force that pulls objects toward the surface of the earth?** (*gravity*)
 - Expand the definition of gravity to include the relationship between mass and gravitational pull.
 - **What is friction, and how does it affect the motion of an object?** (*Friction is a force that converts energy to heat when objects rub together. This means that objects have less kinetic energy and slow down.*)

2. Lead the students in a discussion about how objects can overcome gravity and move through the air. Ask:
 - **What objects have you seen in real life that fly through the air, even though gravity is pulling them toward the ground?** *(Possible answers may include: Airplanes, helicopters, hot air balloons)*
 - **What parts do these objects have that enable them to move through the air?** *(Possible answers may include: wings, blades, motors)*
 - **Why do you think these objects do not fall to the surface of the earth, even though gravity is pulling them in that direction?** *(Call on a few students to share their ideas.)*
3. Ask the students if they have ever seen a helicopter before- either in a picture/video or in real life. Show the students images of helicopters provided in this curriculum. It is suggested that the instructor also show students a video of a flying helicopter (i.e. from YouTube). Ask students to share their observations about the helicopters in the photos and video.
 - **What different parts do you see on the helicopter?** *(Guide students to observe that the helicopter has a main body and blades)*
 - **How are these parts moving?** *(Guide students to observe that the blades on top of the helicopter body and behind it spin)*
 - **How does the helicopter move through the air?** *(Guide students to observe that the helicopter can move in all directions: Up/down, side-to-side, and forward/backward)*
4. Ask students to open their notebooks to page 27. Go over the parts of the helicopter in the diagram:
 - The body of the helicopter is where the people or objects are.
 - The blades of the helicopter spin. As they spin they move against the air around them, creating friction. This friction creates a force called **drag**, which causes the helicopter to move opposite to the force of gravity- so depending on how fast the blades spin and how they're angled the helicopter moves in different directions.
 - Follow the "How Helicopter Works" link and choose additional background information to share with students.
5. Review what students learned about engineers and the engineering design process in the previous activities. Explain to the students that they are going to be engineers again, but will have a different problem to solve for this activity. Write the goal on the board:
 - **Problem:** A hurricane has caused damage which has blocked off-road access to a town. Supplies and medicine need to be dropped to the town from the air without being damaged.
 - **Goal:** Design and create a paper-copter which will use drag to descend to the ground as slowly as possible from a given height.

6. Ask the students: **“Now that we have our goal, where should we start in the engineering design process?”** *(We should ask questions to identify criteria and constraints as well as to explore any science and math content we will need to know to solve the problem.)*
7. Record students’ questions on the board. Make sure the following questions end up on the board:
 - **What is a “paper-copter,” and how is it similar/different to a helicopter?**
 - **Advanced: What is the mass of the medical supplies?**
 - **Where will the paper-copters fly?**
 - **What materials can we use?**
 - **How much time do we have?**
 - **How will we measure our design’s success?**

Teacher Tip: Drop Height

The paper-copters will work most efficiently when dropped from a greater height. If you have access to stairs, it is recommended that you use them. Otherwise, provide a safe surface for students to stand on. In either case, measure the height from the ground students will drop their copters from, and provide this height to students either in inches or cm (whichever you are currently using in class).

Paper Copter:

- Show students an assembled paper-copter. Create a Venn Diagram on the board and have students compare the paper-copter to a helicopter. Write their observations in the diagram- answers will vary, but make sure the following observations end up on the board, and discuss how some of these differences are due to the paper-copter being a model:
 - The paper-copter does not have a motor and the helicopter does.
 - The helicopter can move in all directions (because of the motor) while the paper-copter can only slow its descent to the ground.
 - Each is made of different materials.
 - The paper-copter is much smaller than a helicopter.
 - Paper-copters will transport the mass of the medical supplies to the ground.

Where will the paper-copters fly?

- Show students where they will drop their paper-copters from so they can visualize the drop height.

Time: (show the students each corresponding page in their notebooks)

- Each student will have 5 min. to imagine ideas in their notebooks.
- Teams will then collaborate for 5 min. to develop a plan.
- Once the plan has been approved by the teacher, teams will have 15 min. to create their designs. Any changes to the designs should be reflected in the plan.

- We will test the height, strength, and stability of our designs. Teams will have 10 min. to make improvements to their design.

Materials:

- Students will receive 2 sheets of paper – 1 copy and 1 cardstock- and 1 ft. of tape. Students will create their own paper-copter body- draw it and cut it out. Students will create their own paper-copter blades to add to their copter body. Students will receive 1 additional sheet of paper (either copy or cardstock, their choice) and 1 additional foot of tape during the improve stage. 5 paper clips will be used to simulate the 5 g of supplies being transported. Students can add the paper clips wherever they want on their paper copter.

Teacher Tip:

If it is too much of a struggle for students to create their own copter body from scratch, give groups the paper copter template handout. Students can cut out the size body they want for their paper-copter and modify it. If you choose to do this, require students to make a minimum number of alternations to the template (recommended: 3 changes).

How will we measure our design's success?

- Give students a digital timer to track their drop time. Students will count how many seconds their paper-copter takes to reach the ground after it is released from the set height. Explain that paper-copters must be *dropped*, and groups cannot toss the copters up to a higher height to try to gain more time. Students will compare the time of the 1st and 2nd test in a bar graph in their notebooks and determine whether their first or second prototype was more successful. Demonstrate this test process for students using a template.
- Explain that the paper-copter needs to drop as slowly as possible so that the supplies are not damaged when it hits the ground. You can relate the need for this to parachutes.

Activity (45 min.)

Imagine

1. Have students remind you of the next step in the engineering design process. (*imagine*) The basic and advanced imagine stages are different- find your version below and follow its procedures.
2. Have students open their notebooks up to the “Imagine” portion. Show students the size test paper-copters: Large and small. Explain that during the imagine portion, students will observe a paper-copter with each blade size dropping from the same height. Show students where they will record drop times for each size in their notebook. Clarify: **Is a greater or lesser drop time more successful?** (*A greater drop time is more successful because it will be more likely to keep the supplies from getting damaged from the fall.*)
3. Ask a volunteer student to measure the length and width of a large and small blade (either cm or inches, whichever students are currently using in class). Calculate the perimeter and surface area for each blade size (using whichever method students have learned in math). Record these measurements in student notebooks.
4. Ask students to predict **which blade size will be more successful**. Have students explain the reasoning behind their predictions.
5. Test each blade size according to the procedures for the basic shape test. Have students record results.
6. Guide students to evaluate test results.
 - Which blade size was more successful? (*It should have been the larger blade size. It is recommended to educators to test the models ahead of time to ensure valid results.*)
 - Why is a larger blade size more successful? (*There is more surface area creating more friction and thus more drag.*)
 - What other observations did students make, other than time? (*Students should observe that the smaller blades had a very smooth fall, while the larger blades flopped and caused the copter to drop haphazardly. The larger size may need to be tested more than*

Teacher Tip:

For the imagine tests, it is recommended that the teacher drop all of the paper-copters while students observe and record drop times. This keeps the science experiment as accurate as possible while also demonstrating for students the proper testing procedure.

Teacher Tip:

Students may observe that the different sized paper-copters will have different masses. While this is true, the difference in mass is very small and does not have a significant effect on the test results. However, if you wish to conduct a more accurate science experiment, trim the paper copter body of the larger copter until it is the same mass as the smaller one. Use a scale to check.

once if it tipped sideways. This accuracy of the smaller blade is something important to consider.)

Plan

7. Ask students to remind you of the next step in the EDP: Plan.
8. Have students open to the planning portion of their notebooks. Give them 5 min. to create a plan with their groups according to the instructions in their notebook.
9. Circulate during this time, asking students questions:
 - What do you think about _____'s idea?
 - Has everyone gotten a turn to share?
 - What have you seen in real life, or what past experience, makes you think your design will be successful?
10. After 5 min., check each group's design for approval. Retrieve the sample materials.

Create

11. Ask students which step is next in the engineering design process. (*create*) Tell students that they will have 15 min. to create their paper-copters. Remind students that they can make changes to their design as they build, but that these changes should also be changed in their plan.
12. Give each group their materials and set a timer for 15 min. During this time, students should record the process of creating their design in their notebooks, including any changes they've made to their designs. Circulate during this time, asking students questions:
 - How did you come up with this idea?
 - Does your design look like anything you've seen in real life?
 - What sort of changes have you made to your design so far? Why? Have you recorded this in your notebook?
 - Have you recorded what you've done so far in your notebook?
 - Why do you think your design will be successful?

Teacher tip:

Students may choose not to make their design symmetrical- i.e. different sized/shaped blades. Do NOT require students to make their design symmetrical, as it provides a great learning opportunity for students to observe how an asymmetrical design performs. Definitely ask students during testing to observe the difference in success between symmetrical and asymmetrical designs.

In the advanced notebook, have students write the perimeter and surface area of each blade if they are different.

Students may also choose to add additional blades. Again, have them draw/record data for additional blades in their notebooks if it differs from the others.

13. After 15 min., have groups stop building. Then, test each group's design one at a time while the rest of the class watches. For each group:

- Have the group share their idea with the rest of the class and briefly explain how they came up with the design.
- Follow testing procedures from "Imagine" for each group and have students record their group's results.
- Have students compare designs- how were they similar/different? What do students think affected the success of each design?

Improve

14. Ask students which step is next in the engineering design process. (*improve*) Tell students that they will have 10 min. to improve their designs. Remind students that they can make changes to their design as they build, but that these changes should also be changed in their plan.

15. Give each group their additional improve materials.

16. Set a timer for 10 min. Circulate during this time, asking students questions:

- What was successful about your design in the first test? What failed in your design in the first test?
- How are you planning to improve your design based on test results?
- What sort of changes have you made to your design so far? Why?
- Have you changed these in your plan as well?
- Why do you think your improved design will be more successful than your first design?

Teacher Tip:

For groups with very successful designs, add additional paper clips. Students will need to make changes to account for this additional mass.

17. After 10 min., test each group's design one at a time while the rest of the class watches. For each group:

- Have the group share the changes they made to try and improve their design.
- Re-test according to testing procedures, and have students record results.

Reflection

1. Ask the students:

- Was your second design more successful than your first design? Why or why not?
- What did different groups' designs have in common? Did any of these commonalities seem to contribute to the success of the designs?
- How were different groups' designs unique? Did any of these differences seem to contribute to the success of the design?
- How would you improve your team's design if you had more time?

2. Have students record their thoughts in the reflection portion of their notebooks.

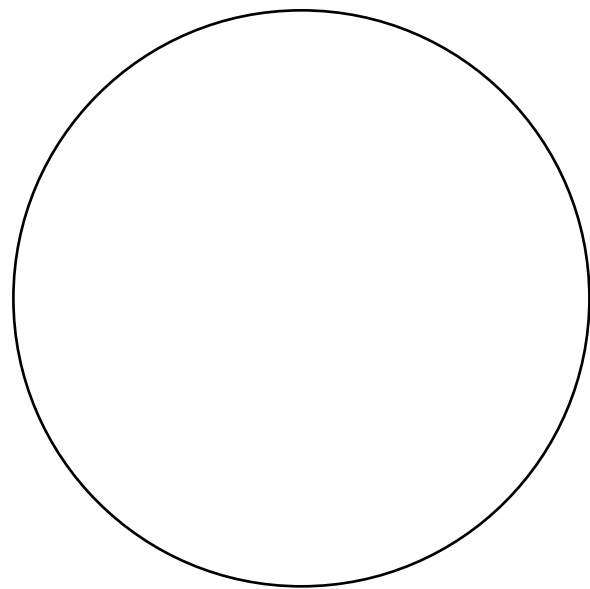
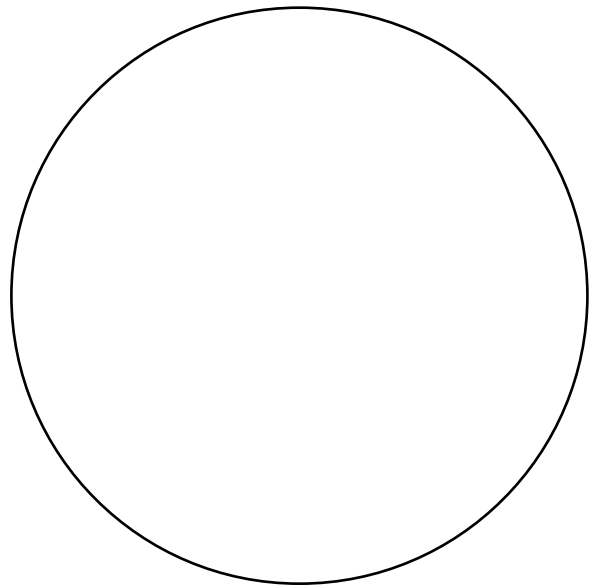
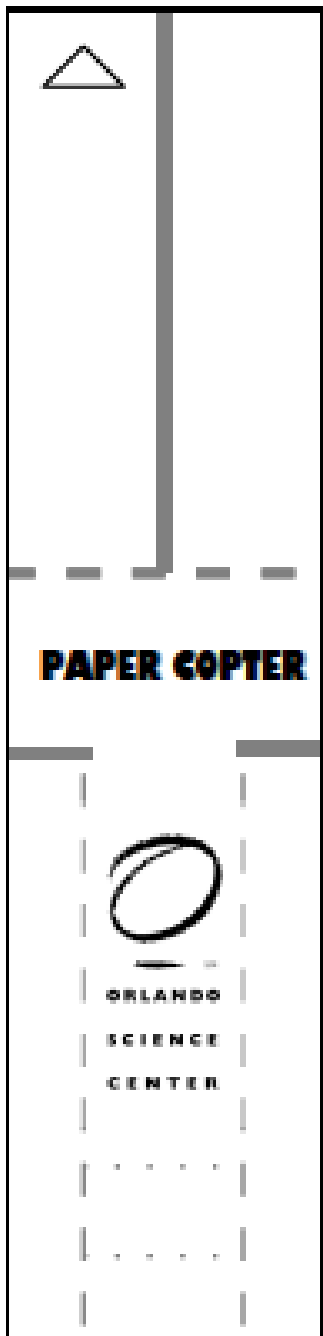
Extension Activity

The following resource provides an additional extension and reinforcement activity.

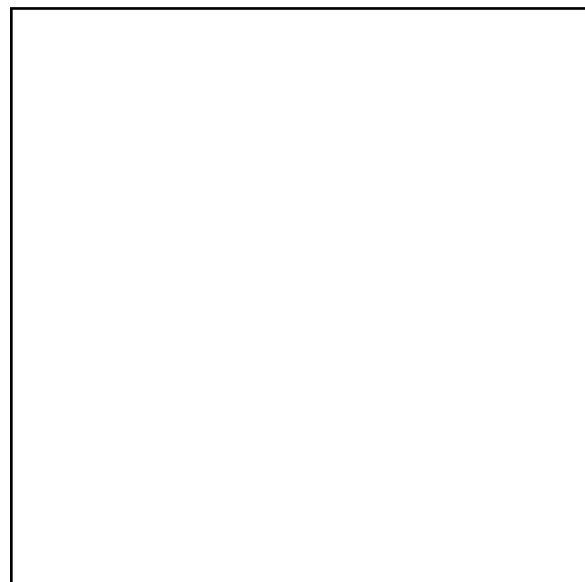
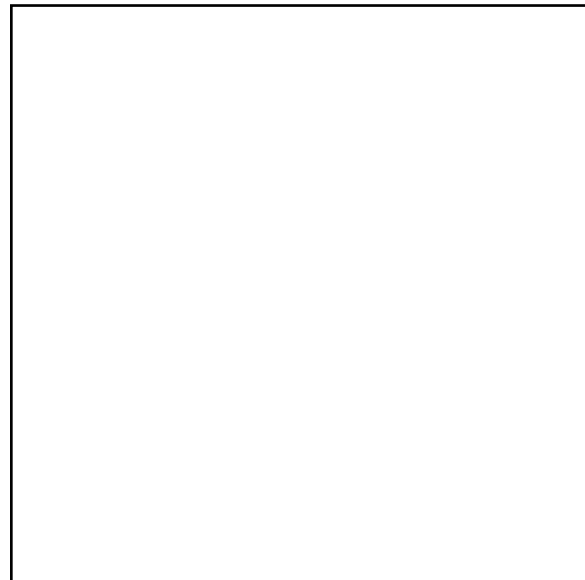
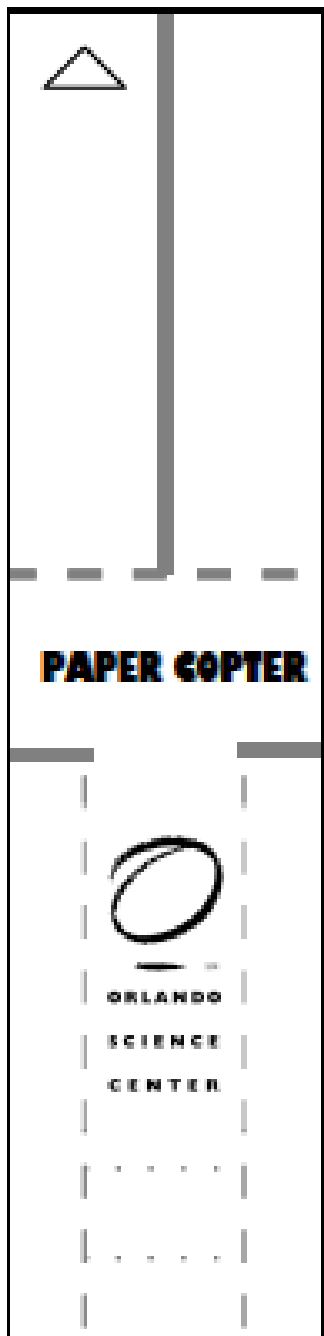
- “What a Drag!”
- https://www.teachengineering.org/activities/view/cub_airplanes_lesson05_activity1



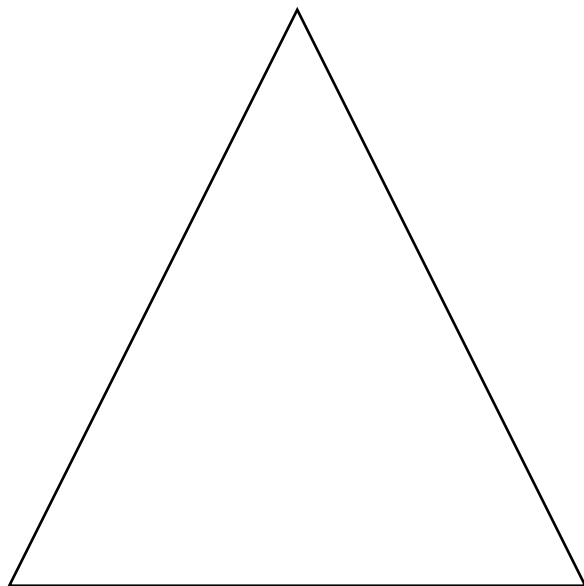
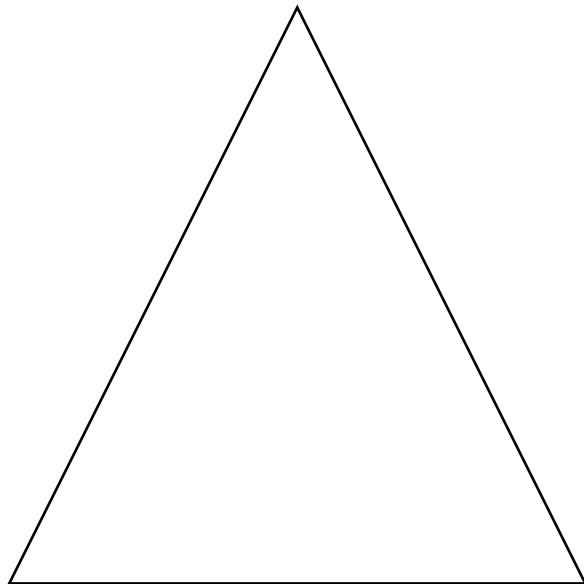
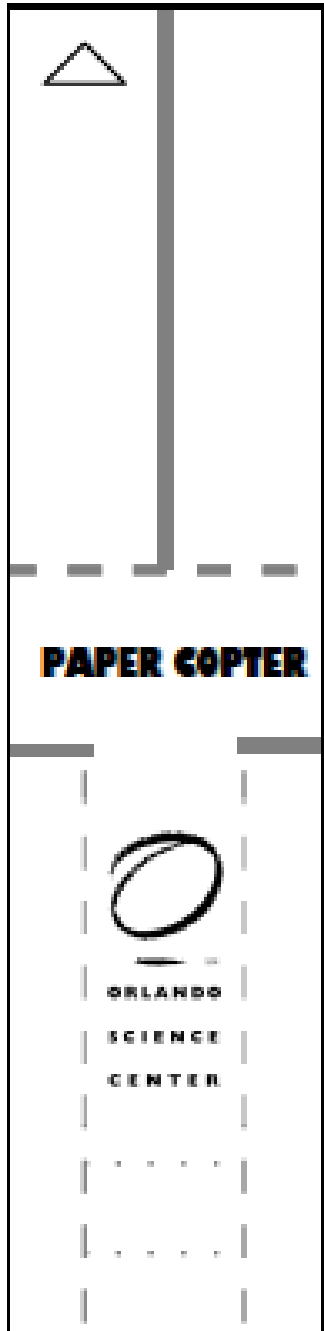
Paper copter shape test: circle



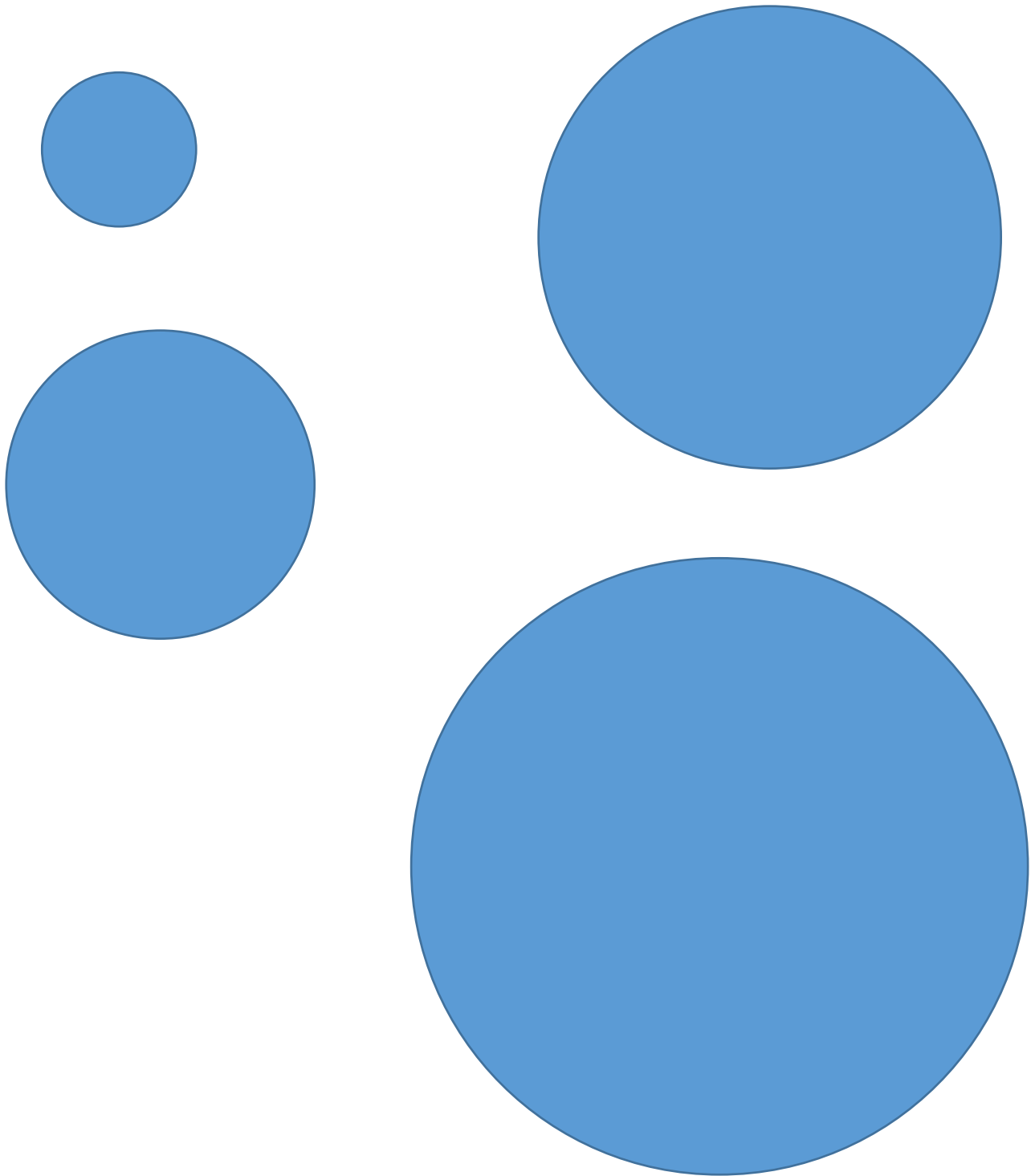
Paper copter shape test: square

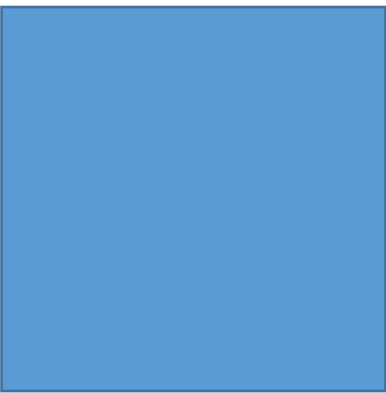
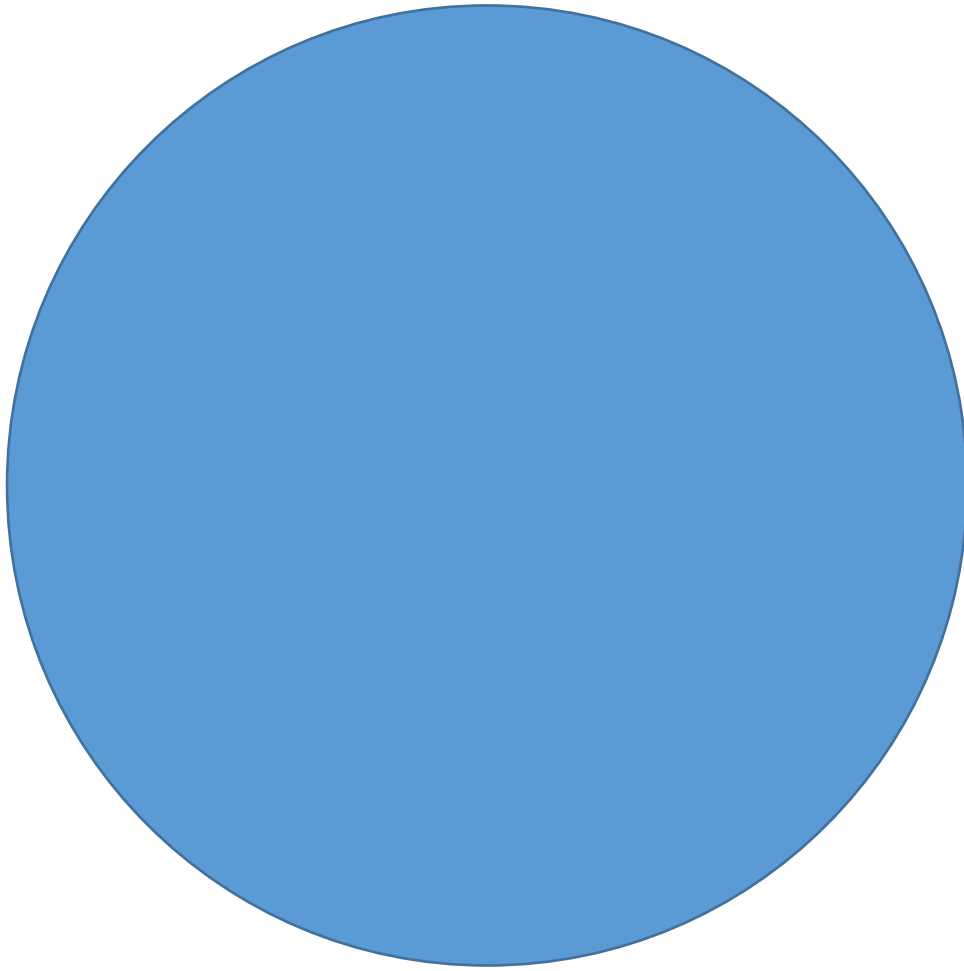


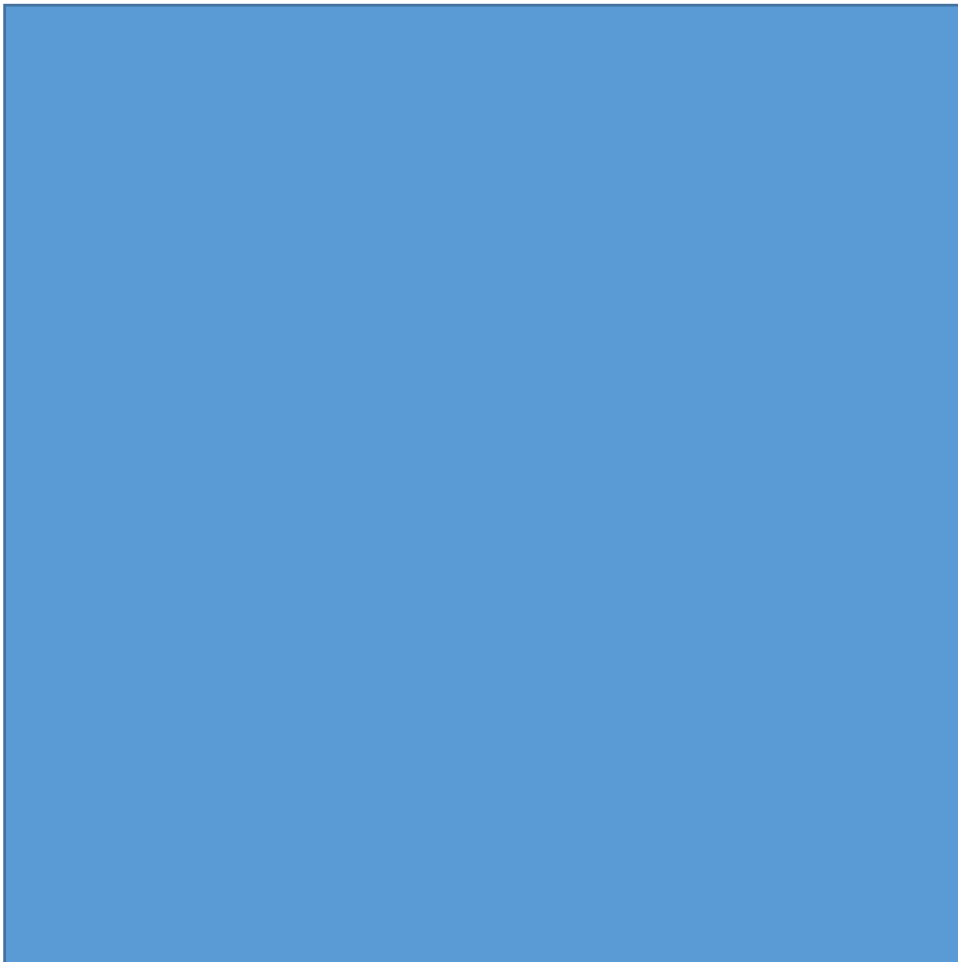
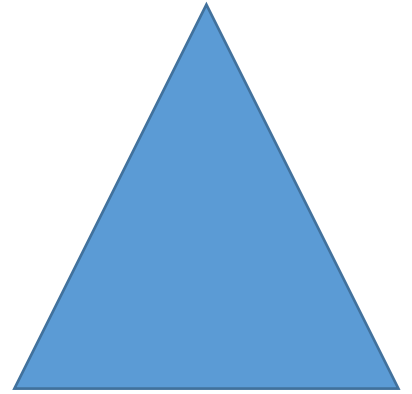
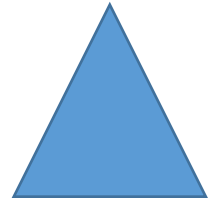
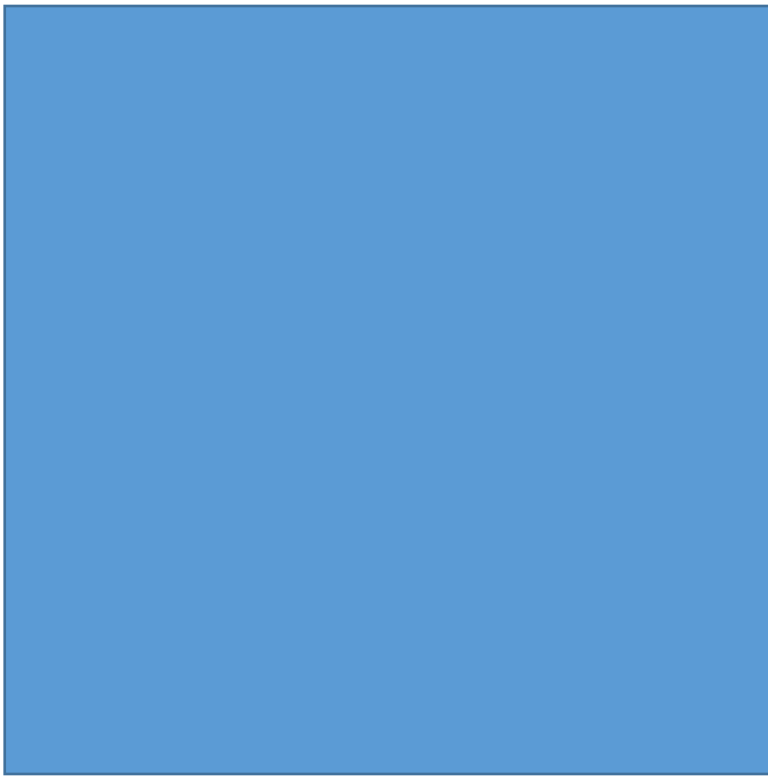
Paper copter shape test: triangle

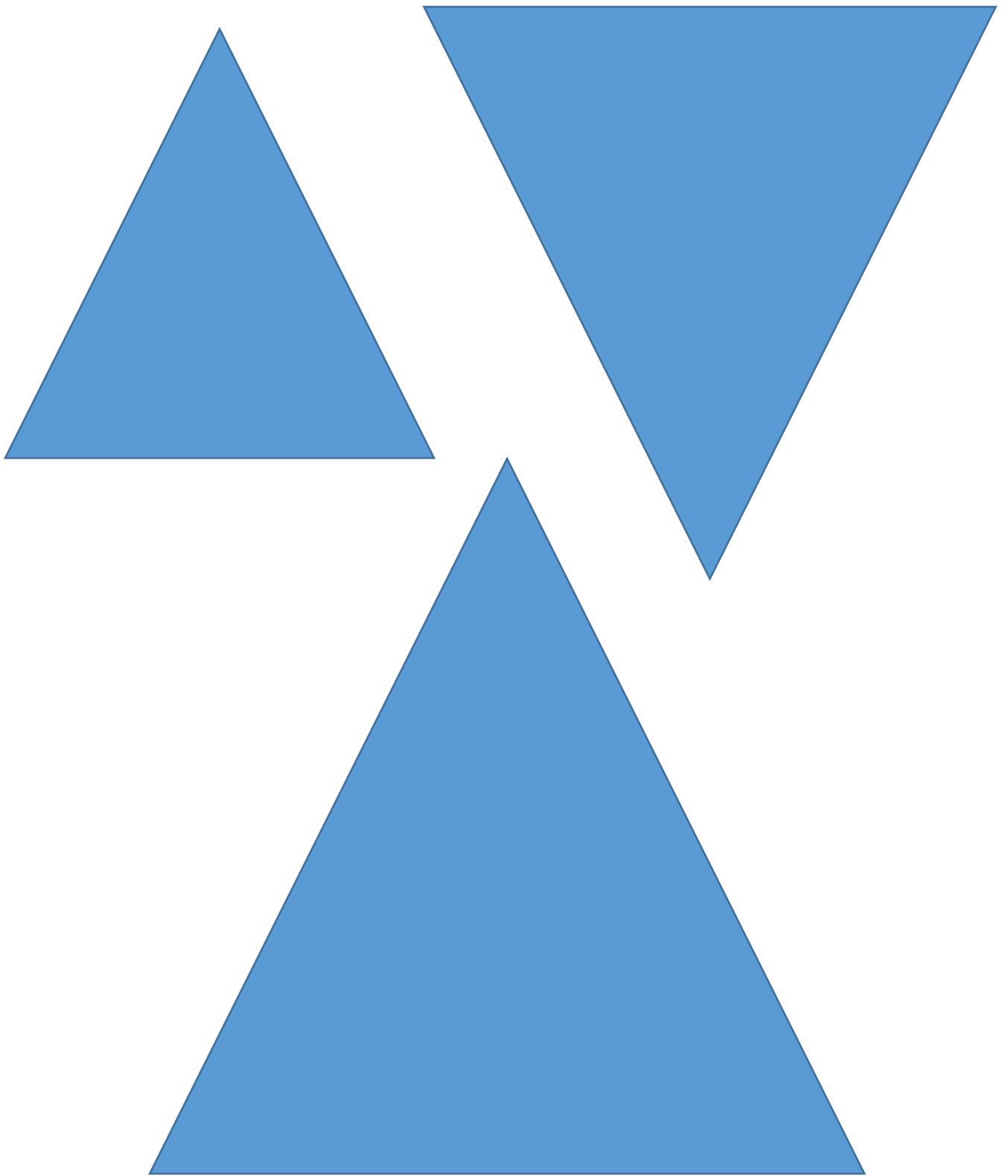


Blade Shapes Template

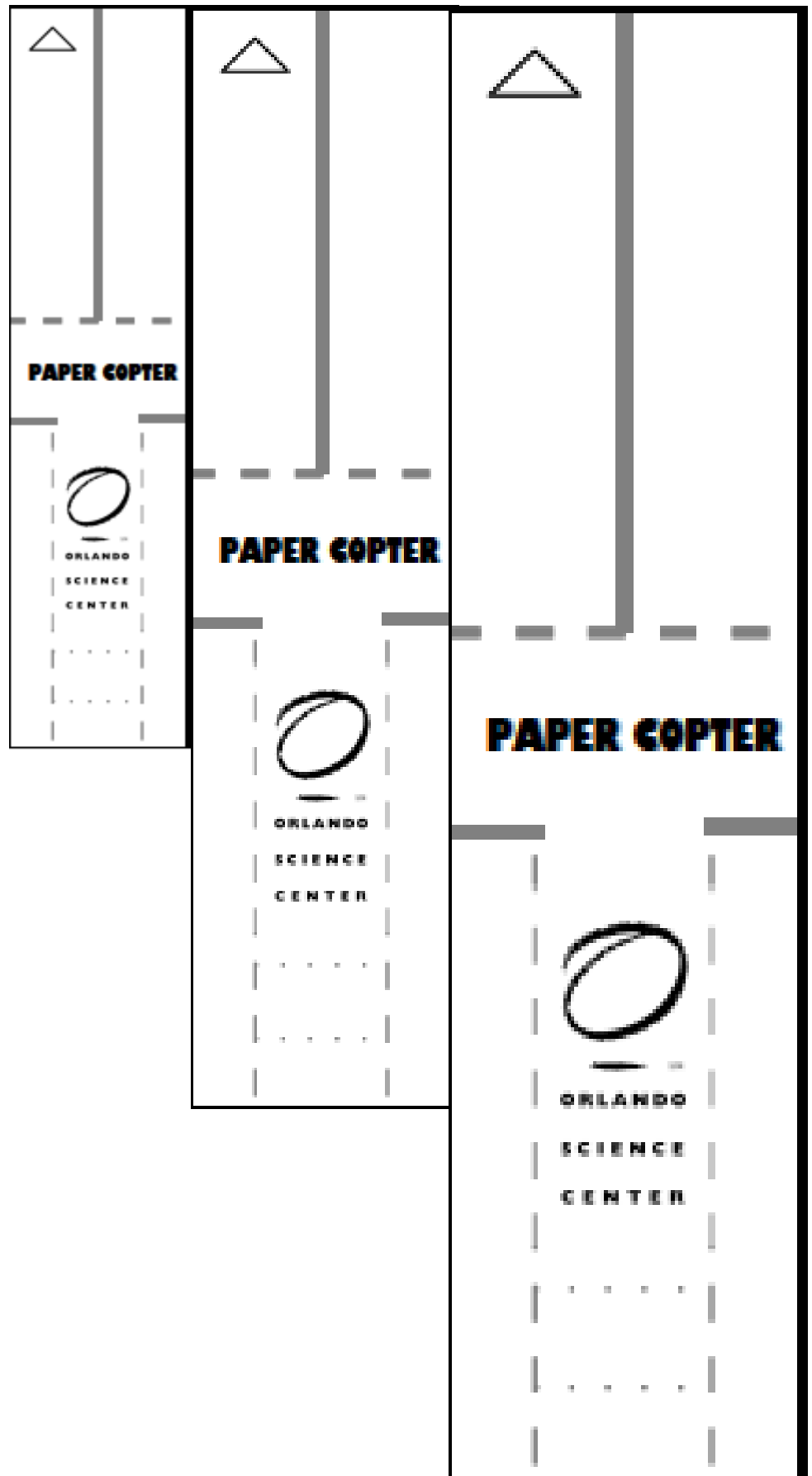




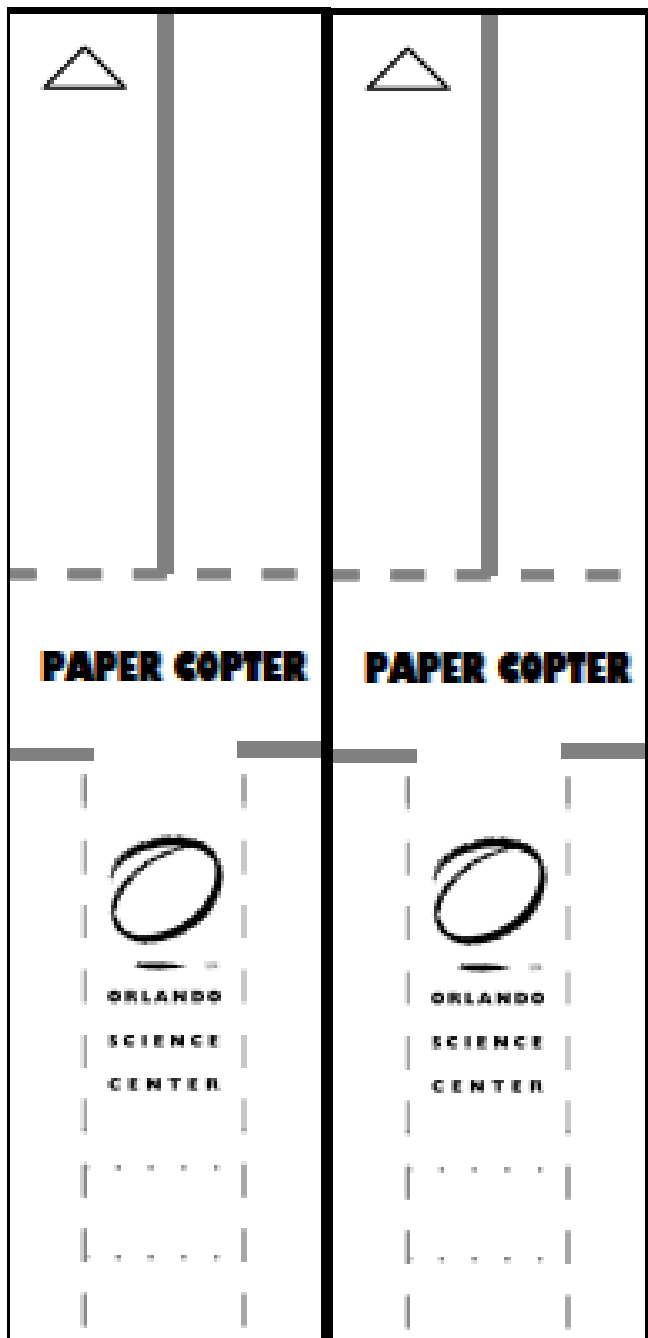




Paper copter Test: Size



Paper Copter Test: Mass



Design a Telephone

Prep: 5 – 10 min.

Activity: 65 min.

Science Topic: Energy and sound

Vocabulary

- energy
- vibrate
- matter
- physical properties
- molecules
- density

Learning Objectives: Students will...

- Explore how to create telephones that will transfer sound clearly.
- Investigate how different materials transfer sound energy.
- Use empirical evidence to explain how density and other physical properties affect how material transfers sound energy.

Overview

In this pre-activity, students explore how different materials transfer sound energy. Students use the engineering design process to find a possible solution to the problem: Create a telephone which transfers sound clearly.

Students must collaborate with their peer(s) to design a model telephone which will meet their developmentally-appropriate criteria. Students will use developmentally-appropriate measuring tools to determine whether their structure has met the criteria and whether their second prototype has improved in meeting these criteria.

Students work within materials and time constraints as they attempt to solve the problem. Students receive a set number of developmentally-appropriate building materials and create, test, and improve their designs. Students evaluate their designs to determine whether they have met the goal criteria.

Students share their designs with their classmates and compare different designs to appreciate the creativity that goes into engineering.

Background

Review from the previous activity: energy, matter, physical properties, solid, liquid, and gas.

All matter is made up of tiny particles called **molecules**. We cannot see individual molecules with our eyes, but we can sense other things about them.

We can see and feel solids, liquids, and gases. These different states of matter look, feel, and behave differently because of the space between molecules. (See Play Dough Activity for more information on states of matter) We call the space between molecules **density**. More dense objects have molecules closer together, and the opposite is true for less dense objects.

Sound is a type of energy. Sound is created through a series of **vibrations**:

- Something begins to move- for example, a car motor.
- The movement causes surrounding molecules to vibrate- for example, the molecules in the air around the motor vibrate as the vibrating motor collides against them.
- As molecules vibrate, they hit other molecules and cause them to vibrate in turn.
- Eventually, the vibrations reach molecules next to our eardrum, causing our eardrum to vibrate. Our brain interprets this as sound.

The closer molecules are together, the faster vibrations can be transferred from one to another, and the less energy is lost before it is transferred to another molecule. Thus, more dense objects (solids) transfer sound more quickly. Less dense matter (gas) transfers sound less quickly. This is why a boat motor on the other side of the lake sounds much louder when you are underwater than when you hear it through the air- the liquid molecules between you and the motor are much closer together than the gas molecules in the air.

Modern telephones convert sound to electrical energy. However, simple telephones can be constructed to move sound vibrations through solid materials like cups and wires. Students can hear how sound is amplified through solid materials when they hear more clearly through the model telephone.

Resources

For more information, please access the following resources:

- How Stuff Works
“How Telephones Work”: <http://electronics.howstuffworks.com/telephone.htm>
- Science Kids
“Sound Facts”: <http://www.sciencekids.co.nz/sciencefacts/sound.html>

Pre-Requisite Knowledge

Students should have grade-appropriate comprehension of the following concepts:

Basic (students do not necessarily need to be able to do these independently)

- Define and identify states of matter: Solid and liquid.
- Make observations about the properties of materials such as shape, color, temperature, and texture.
- Recognize that the shape of materials can be changed by tearing, crumpling, smashing, and rolling.
- Energy is an object's capability to move.
- Connecting counting and cardinality.
- Either the ability to “count on” and “count back” or add and subtract.
- Comparing greater than, less than, and equal to.
- Motor skills to cut using scissors and use tape.

Advanced

- How to measure with a ruler to the nearest inch.
- Explain states of matter: solid, liquid, and gas.

Pre-Requisite Resources: Please see the following pre-activities for educators who have not yet covered pre-requisite science concepts in the classroom:

- Design Play Dough

Materials

For the Class:

- Engineering Design Process (on the board or on chart paper)
- Basic Materials
- Several of each: Small, medium, and large aluminum cans
- Spool of soft wire: one thick and one thin
- Wire clippers

For Each Group of 3 – 4 Students

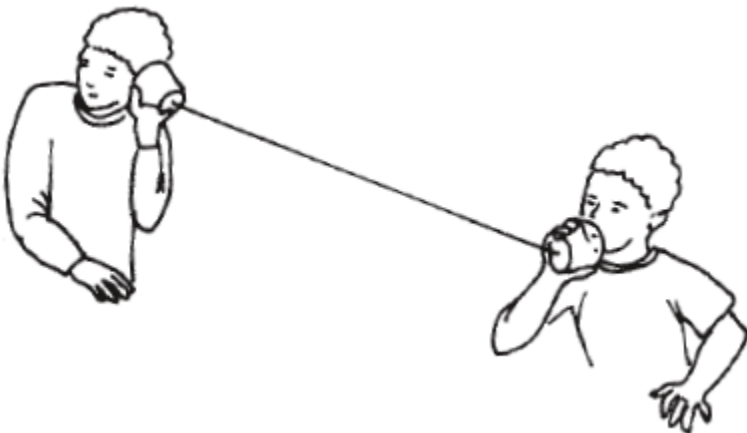
- Bag of sample materials
- scissors
- 2 ft. of duct tape

For Each Student

- pencil
- advanced engineering notebook

Prep

- Create an example telephone. Tape a length of string between the bottom of the base of two cups.



- Place materials on a table to be the “materials store.”
- Sand down the edges of the aluminum cans so they are not sharp and cannot harm students.
- Prepare one bag of sample materials per group containing all of the basic materials plus:
 - 1 in. of each wire
 - 1 of each: large, medium, and small aluminum can
- Measure a distance of 10 feet next to each group’s workspace. Place masking tape on the floor to mark the distance of 10 feet so students know how far apart to stand when testing.

Introduction (15 min.)

1. Review with students what they have learned about matter. Ask:
 - **What are the properties of matter?** (*Anything we can observe using our senses- i.e. shape, size, color, temperature, texture.*)
2. Review with students what they have learned about energy:
 - **What is energy?** (*Energy is the ability to move*)
 - Discuss different types of energy your students have learned about.

3. Ask students:
 - **What body part do we hear with?** (*Our ears*)
 - **What do you know about how we hear sound?** (*Allow a few students to share prior knowledge*)
4. Explain: **Sound is a type of energy created from vibrations.**
5. Have three students come to the front of the room and hold hands in a line. Explain: **Molecules are tiny particles that are too small to see. They build up to create all matter. These three students each represent a molecule.**
6. Call a fourth student to the front of the room and hold hands with a student at the end of the line. Explain: **This student represents the source of a sound. Sound begins with very fast movements called vibrations- like when you talk, your vocal cords vibrate.** Have students place a hand on their throat to feel vibrations when they talk.
7. Have the student representing sound source talk. As they talk, explain: **As something vibrates, it collides with the molecules around it. These three students represent air molecules. As this student is talking, his/her vibrating vocal cords hit the air molecules around it, causing them to vibrate.** Have the student closest to the “source” start to wiggle to represent a vibrating molecule.
8. Explain: **These vibrating molecules collide with molecules next to them, causing them to vibrate, and so on, from molecule to molecule. This is how sound travels.** Have the second molecule vibrate, and then the third.
9. Explain: **I represent an eardrum. When the vibrations are transferred to molecules next to my eardrum, it causes my eardrum to vibrate. My brain interprets this as sound.** The instructor should stand next to the third molecule and wiggle.
10. Ask: **Are molecules closer together or further apart in solids, liquids, and gases?** (*Closest in solids, further apart in liquids, and furthest apart in gases.*) Have the molecules demonstrate the vibrations again:
 - Shoulder-to-shoulder to represent solid
 - Holding hands as far apart as possible to represent liquid. Drop hands, then the molecule has to walk next to the next molecule to transfer the vibration.
 - Standing very far apart. The molecule has to walk next to the next molecule to transfer the vibration.

11. Ask: **Which state of matter did sound travel through the fastest?** (*Solid*) **Slowest?** (*Gas*) **Why?** (*The further apart the molecules are, the further they have to travel to transfer the vibrations, and the longer it takes*)
12. Explain that the space between molecules is density. More dense objects have molecules very close together. Less dense objects have molecules very far apart. We just learned that more dense objects transfer sound more quickly.
13. Review the Engineering Design Process with students and give them their problem and goal:
- **Problem:** A kid has written to a toy company requesting a toy that will help them talk to their friend next door that doesn't need electricity to work.
 - **Goal:** Design a telephone that can transfer sound a distance of 10 ft. clearly without electricity.
14. Ask the students: **"Now that we have our goal, where should we start in the engineering design process?"** (*We should ask questions to identify criteria and constraints as well as to explore any science and math content we will need to know to solve the problem.*)
15. Record students' questions on the board. Make sure the following questions end up on the board:
- **What do you mean by "clearly?"**
 - **How will the success of our design be measured?**
 - **What materials will we have?**
 - **How much time will we have?**
16. **Clarity/Success:** Explain that the success of the design depends on how clearly you can hear someone on the other end of the telephone. A student will WHISPER 10 words into one end of the telephone. The student listening on the other end will write down what they hear. The telephone will get a score out of 10.
17. **Materials:** Show the students the example telephone so they can see the different parts their phone system needs to have. Show them how one person speaks on one side while the other listens on the other side. Students will choose a material for the speaking/listening part from the available cups. They do not have to choose the same material for each side, and can even combine different materials on the same side if desired. Show the students the different materials and sizes available. Students will choose materials for the string/yarn/rubber band connecting each cup, as well as how long the string/yarn/rubber band will be.
- Students have additional choices of the cans and wires. The teacher needs to cut the wire for students using wire cutters. Do not let students use these materials who do not have the maturity and motor skills necessary to prevent injury.

- Set a “budget” limit as you see appropriate for how many materials students may select to use.

18. Time:

- Each student will have 5 min. to imagine ideas as a group.
- Teams will then collaborate for 5 min. to develop a plan.
- Once the plan has been approved by the teacher, teams can begin creating their telephones. Unlike in the last activities, students can test and improve as they go, as many times as they can, in 25 min. However, each time they finish a prototype they must score, evaluate, and then begin a new, improved prototype.
- After 25 min. we will share our final telephones and explain the improvements we made throughout.

Activity (45 min.)

1. Have students remind you of the next step in the engineering design process. (*imagine*)
2. Have students open their notebooks up to the “Imagine” portion. Give each group a sample of their materials. Clarify that these are not part of their building materials, so they don’t have to worry about damaging them.
 - Have students experiment with their materials WITHOUT building. They can talk into ONE cup and listen on the other end to see which end works better for talking/listening and to compare materials and sizes.
 - During this time, circulate and ask students questions such as:
 - Which materials feel more/less dense? How do you know?
 - Which materials seem to transfer sound better? Why do you think that is?
 - Which materials will be easier to use to connect the speaking/listening pieces?
3. After 5 min., ask the students which step is next in the engineering design process. (*plan*) Set expectations for how students will interact- taking turns, speaking kindly, voting on ideas, etc. Emphasize that groups can combine ideas- they don’t just have to choose one. Tell the groups to draw their ideas in their notebooks.
4. Give students 5 min. to collaborate and form a plan. Students may continue experimenting with the sample materials, but they may NOT build yet. Circulate during this time, asking students questions:
 - What do you think about _____’s idea?
 - Has everyone gotten a turn to share?
 - What have you seen in real life, or what past experience, makes you think your design will be successful?

5. After 5 min., check each group's design for approval. Retrieve the sample materials.
6. Ask students which step is next in the engineering design process. (*create*) Tell students that they will have 25 min. to create their telephone. Remind students that they can make changes to their design as they go, but that these changes should also be changed in their plan.
7. Give each group their building materials and set a timer for 25 min. During this time, students should record the process of creating their design in their notebooks, including any changes they've made to their designs. Circulate during this time, asking students questions:
 - How did you come up with this idea?
 - Does your design look like anything you've seen in real life?
 - What sort of changes have you made to your design so far? Why? Have you recorded this in your notebook?
 - Have you recorded what you've done so far in your notebook?
 - Why do you think your design will be successful?
8. Make sure groups are testing as they finish a prototype, recording results, evaluating, and then improving by making changes to their prototype. Make sure students are whispering so they cannot "cheat" and hear the student talking without the telephone. Also, make sure they are standing the correct distance apart- 5 for basic and 10 for advanced.
9. After 25 min., have each group share their design. Let groups try each other's design out. For each group:
 - Have the group share their improved design with the rest of the class and briefly explain their process.
 - Have groups explain any improvements they made from their original design and why.

Teacher Tip:

If students receive 10 out of 10 points, increase the number of words that need to be transferred clearly.

Alternatively, you can increase the distance between the speaker/listener.

Reflection

- I. Ask the students:
 - Was your second design more successful than your first design? Why or why not?
 - What did different groups' designs have in common? Did any of these commonalities seem to contribute to the success of the designs?
 - How were different groups' designs unique? Did any of these differences seem to contribute to the success of the design?
 - How would you improve your team's design if you had more time?

2. Have students record their thoughts in the reflection portion of their notebooks.

Extension Activity

The following resource provides an additional extension and reinforcement activity.

- “Sound Sandwich”
- <http://www.exploratorium.edu/afterschool/activities/index.php?activity=1>

Plant Hydrating System

Prep: 30 min.

Activity: 120 min.

Science Topic: Needs of Living Things

Learning Objectives: Students will...

- Explore how to create a hydroponics system which meets the needs of a plant.
- Investigate how properties of materials affect water absorption.
- Use empirical evidence to explain whether a design meets the needs of a living thing.

Vocabulary

- habitat
- gravity
- measure
- volume
- hydroponics system
- filter
- roots
- stem
- leaves
- needs

Overview

In this pre-activity, students explore how to meet the needs of living things. Students use the engineering design process to find a possible solution to the problem: Create a hydrating system which meets the basic needs of a plant.

Students must collaborate with their peer(s) to design a hydrating system which will meet their developmentally-appropriate criteria: Students following the basic lesson plans will design a filtration system while advanced students will design a hydroponics system. Students will use developmentally-appropriate measuring tools to determine whether their system has met the criteria, and whether their second prototype has improved in meeting this criteria.

Students work within materials and time constraints as they attempt to solve the problem. Students receive developmentally-appropriate building materials and create, test, and improve their designs. Students evaluate their designs to determine whether they have met the goal criteria.

Students share their design with their classmates and compare different designs to appreciate the creativity that goes into engineering.

Background

All living things have the same basic **needs**: air, water, food, and space. A **habitat** is a space that meets the needs of the plants, animals, and other organisms living within it.

Plants are living things that use energy from the sun, air, and water to make their own food. Plant parts work together to give a plant access to the things it needs to survive.

- **Roots** are structures in a plant which absorb water containing nutrients and minerals from the soil. They also anchor the plant in the soil to keep it from falling over.
- **Stems** provide structural support for a plant and also act as a plumbing system, delivering water and nutrients from the roots to the rest of the plant.
- **Leaves** absorb sunlight, which plants use to create their own food in a process called photosynthesis.

A **filter** is a type of technology that allows some materials to pass through, but not other materials. A filter can also be designed to allow materials to pass through at a specific rate (a set volume in a set amount of time).

Plants naturally grow in soil. Soil contains nutrients and minerals, which are absorbed by water and subsequently pass into a plant through its roots. Therefore, plants grown in soil spend a significant amount of energy growing a root system. Humans have developed alternative ways to provide a plant with its water and nutritional needs. A **hydroponics system** grows plants without the use of soil:

- A solution (a mixture of substances within a liquid, or liquids) of nutrients and minerals is created which meets the exact needs of a specific species of plant.
- The water solution is transported by the hydroponics system directly to the roots of the plant.
- Since a solution is created with the exact amounts of nutrients and minerals the specific species of plant needs, and this is delivered directly to the roots by the hydroponics system, the plant spends minimal energy developing a root system.
- This means that the plant has more energy to spend on growing, flowering, and producing fruit.

Resource (*Please see pre-requisite knowledge for resources about plants*)

For more information about hydroponics systems, please access the following resource:

- “Fullbloom Hydroponics”
<http://www.fullbloomhydroponics.net/hydroponic-systems-101/>

Pre-Requisite Knowledge

Students should have grade-appropriate comprehension of the following concepts:

Basic (students do not necessarily need to be able to do these independently)

- Basic needs of living things, and how these needs are met within their habitats
- Basic parts of plants and their functions
- A basic understanding that gravity is the force which pulls objects toward the earth's surface
- A force is a push or a pull on an object that can change how the object is moving
- How to measure the volume of a liquid using standard units of measurement: mL or ounces
- Connecting counting and cardinality
- Either the ability to “count on” and “count back” or add and subtract using whole numbers
- Comparing greater than, less than, and equal to

Advanced

- Basic needs of living things, how these needs are met within their habitats, and how changes within an environment can affect characteristics of living things
- Explain the process by which plants use energy from the sun, air, and water to make their own food
- An understanding that gravity is the force which pulls objects toward the earth's surface and that it can be overcome by another force
- A force is a push or a pull on an object that can change how the object is moving, and the greater a push or the pull the greater the change in motion
- How to measure the volume of a liquid using standard units of measurement: fractions of a cup ($\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$)
- Add and subtract fractions with the same or different denominators
- Represent and interpret data in a bar graph

Pre-Requisite Resources: The following resources are for educators who have not yet covered pre-requisite science concepts in the classroom:

- Parts of a Plant
“Plant Parts”
<http://www.mbgnet.net/bioplants/parts.html>
- Basic Needs of Plants
“New Plants- FOSS Module”
<http://www.cpalms.org/Public/PreviewResourceUrl/Preview/22812>

Materials

For the Class:

- Engineering Design Process (on the board or on chart paper)
- 1 permanent marker
- 1 pair of sharp scissors
- 1 box cutter or exact-o-knife
- Source of running water
- Building materials (see materials store prep)*

For Each Group of 3 – 4 Students

- 1 ruler
- 1 pair of scissors
- 1 clear, plastic bottle, 2 Liter
- 3 clear, plastic cups, 18 oz.
- 1 measuring cup, in fractions of a cup ($\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$)
- 1 gallon-sized Ziploc bag
- 1 rubber band, very large and thick (Must be large enough to wrap around a 2-liter plastic bottle without distorting the shape of the bottle)
- 1 paper towel
- 1 sponge
- 1 diaper

For Each Student

- pencil
- advanced engineering notebook

Prep

- Prep a container for each group's hydroponics/filtration system using a clear, 2L plastic bottle
 - Use a ruler to measure 8 inches from the bottom of the bottle. Using a permanent marker, mark 8 inches from the base around the bottle, making a mark every inch or so around the circumference. It will form a circle of dots around the circumference of the bottle at an 8" height from the base of the bottle.
 - Note: 8 inches is the height that works for most 2 liter bottles. However, not all 2-liter bottles are shaped the same; the teacher should observe where the curve of the top of the bottle ends and measure to that height

to determine their own height. We recommend creating one bottle first to make sure you have the correct height for the funnel to remain in place without tape. Students need to be able to add and remove the funnel repeatedly, and the tape would interfere with their ability to do so.

- Using an exact-o-knife, cut around the circumference of the bottle along the circle of dots you drew at the 8" height.
 - Note: Once you have cut more than halfway around, the plastic will become more flimsy and it may be easier to finish cutting with a sharp pair of scissors.
- Turn the top of the bottle upside down and place it in the bottom. It will create a funnel sitting at the top of the bottle. If you cut at the correct height, the top will sit in place without needing any tape to hold it there.



- Create a set of testing materials for “Imagine”
 - Using a permanent marker:
 - Label 1 cup per group “sponge”
 - Label 1 cup per group “diaper”
 - Label 1 cup per group “paper towel”
 - Trace a circle the size of the **BOTTOM** of a cup on each of the sponges and paper towels. Using the sharp scissors, cut out the circles on each material. Each group of students will need one circle of each sponge and paper towel.
 - Place one circle of paper towel at the bottom of each cup labeled “Paper Towel.”
 - Place one circle of sponge at the bottom of each cup labeled “Sponge.”

- Cut open the diaper. There will be layers of material that feels similar to stretched out cotton balls. Pull the material out and create a layer of the material at the bottom of each cup labeled “diaper.” The layer should be approx. $\frac{1}{4}$ ” thick.
- Create a set of sample materials for each group of students in a gallon-sized Ziploc bag
 - 1 sponge
 - 1 paper towel
 - 6” yarn
 - 6” string
 - 1 jumbo cotton ball
 - 1” square piece of felt
 - 1” square piece of cotton fabric (i.e. shirt)
 - 1 sock
 - 1” square of paper
 - 1” square of tissue paper
 - 1 coffee filter, size 8-12 cup
 - 1 diaper
- Create a materials store, where students can obtain building materials ** Note: These materials are recommended to place out for student choice for creating and improving their designs. These are the recommended materials, but educators may choose to use less or more materials based on the availability of materials and the needs of their students. It is recommended that educators provide a few types of materials which are inherently absorbent and will not dissolve in water, a few types of materials which inherently will not absorb water and/or will dissolve in water, and a couple of string/yarn like options for shaping materials since tape cannot be used in water.
 - 1 large roll of paper towels
 - Sponges, approx. 50
 - 1 large box of diapers
 - 1 large skein of yarn
 - 1 large spool of string
 - 1 large bag of jumbo cotton balls
 - 1 large bag of felt
 - Several shirts, or other sources of cotton fabric
 - Approx. 20 socks
 - 1 ream of copy paper
 - Large bag of tissue paper
 - Large bag of coffee filters, size 8-12 cup
- Familiarize self with provided budget, which assigns whole dollar values to each unit of material.
- OR determine alternative budget:

- Students choose a total number of materials during create phase, and a set number of additional materials during improve. This is a faster way for students to select materials if an educator is concerned about time.
- Students will use a budget of values made up of numbers used in class (i.e. the educator may prefer to use cent values if students are using decimals rather than whole dollars).

Introduction (15 min.)

1. Review with students what they have learned about the basic needs of living things. Ask:
 - **What are the basic needs of all living things?** (*Air, water, food, and space*)
 - **What is a habitat?** (*A space which meets the needs of the living things within it*)
2. Lead the students in a discussion reviewing what they have studied about plants and their structures in your class:

Teacher Tip:

Expand the discussion to include more details about photosynthesis if you have discussed this process in your class.

 - **How do plants make their own food?** (*Plants use water, air, and energy from the sun to make their own food.*)
 - **What plant structures are used to give plants access to each of these needs?**
 - **Roots** absorb water in the soil, which contains minerals and nutrients present in the soil. Roots also provide structural support.
 - The **stem** transports water from the roots to the rest of the plant. The stem also provides structural support for the plant.
 - **Leaves** absorb air and also absorb energy from the sun.
 - **How have different plant species developed different characteristics to adapt to their habitat?** (*Answers will vary. Example: Cacti have more space for water storage and have needles instead of leaves because leaves provide a larger surface area for evaporation of water to occur.*)
3. Ask students if they have ever heard of a hydroponics system. Explain that plants that grow naturally obtain their nutrients from the soil.
 - As water moves through the soil from the surface downward, it picks up traces of the nutrients present in the soil.
 - The roots of a plant in the soil then absorb this nutrient-rich water and transport it to the rest of the plant.
 - In the “natural” system, the plant must spend a lot of energy growing roots as wide as necessary to cover a greater expanse gather the amount of nutrients it needs to survive and grow.

4. Explain how a hydroponics system works: **Hydroponics systems grow plants without the use of soil.**
 - A **solution** (a mixture of liquid and other substances) of water and nutrients/minerals is created to meet the exact needs of a specific plant.
 - The water solution is transported by the hydroponics system directly to the roots of the plant.
 - Since a solution is created with the exact amounts of nutrients and minerals the specific species of plant needs, and this is delivered directly to the roots by the hydroponics system, the plant spends minimal energy developing a root system.
 - This means that the plant has more energy to spend on growing, flowering, and producing fruit.
5. Explain to the students that they are going to be engineers who will be solving a problem using the engineering design process. Tell the students the problem and goal, and write the goal on the board:
 - **Problem:** A poverty-stricken area needs a more efficient method of growing plants so they can produce more food.
 - **Goal:** Design a hydroponics system that will transport water to a plant.
6. Ask the students: **“Now that we have our goal, where should we start in the engineering design process?”** *(We should ask questions to identify criteria and constraints as well as to explore any science and math content we will need to know to solve the problem.)*
7. Record students’ questions on the board. Make sure the following questions end up on the board:
 - **How much water does the hydroponics system need to transport to the plant?**
 - **What type of container will our hydroponics system be in?**
 - **What materials can we use to build our hydroponics system?**
 - **How long do we have to create and improve our hydroponics system?**
 - **How will we know if our hydroponics system is successful?**
8. After students have finished brainstorming questions, answer each of them. Record criteria and constraints on the board or on chart paper. Students should record the criteria in the appropriate places in their notebooks.
 - **How much water does the hydroponics system need to transport to the plant?**

- The hydroponics system must transport at least 1/8 cup of water to the growing area for the plant.
- Have students record this volume under the goal of this activity in their engineering notebook.
- **Filter Container:**
 - Show students an empty container (prepped 2L bottle).
 - Explain that the base is where the water will be placed for testing.
 - Point out the top piece (upside-down top portion of the bottle). Explain that students will place any materials they wish to use to create their hydroponics system in this top piece. Clarify that students may also descend materials from the top part into the bottom (i.e. if students wanted something to hang out of the spout to reach the bottom of the base, like a rope).
- **Filter Materials:**
 - Explain that during the imagine and plan time, students will receive a sample of materials so they can explore their properties. Students will have to work within a budget to select which materials they will use.
 - During the create time, students will take their budget page to the materials store, where they can gather their needed materials.
 - During the imagine time, students will receive the same budget to obtain all new materials. Materials from the first test CANNOT be reused, since they will be wet and will affect how absorbent the design is for test 2.
- **Time:**
 - Students will have 15 min. to imagine, during which they will explore absorption.
 - Students will have 10 min. to plan.
 - Students will have 20 min. to create.
 - Students will have 20 min. to improve.
- **Evaluating Design Success:**

Unit of Measurement

The advanced lesson of this activity uses fractions of a cup as the unit of measurement in order to integrate at least 3rd grade+ standards using fractions. However, it is up to the teacher's discretion which standard unit of measurement to use. Please be aware that the advanced student notebook uses fractions of a cup as the unit of measurement.

Content Extension:

If doing the extension lesson provided, the teacher may research the minimum and maximum volume of water/nutrient solution needed by the selected plant. The goal can then be changed to this range of water volume (i.e. 1/8 to 1/4 cup of water).

- Have students open to the testing part of their engineering notebook.
- Students will pour 3 cups of water into the bottom part of the container.
- The top portion, containing the hydroponics system materials, will be placed on top of the base.
- After 1 day, students will measure how much water is in the base of their design. Have students observe the space where they record the volume of water that the hydroponics system absorbed in one day.
- Students will then determine whether their design has met the goal. Students whose designs absorbed less than 1/8 cup of water will improve their designs to meet the goal. Students whose designs absorbed at least 1/8 cup of water will improve their design to absorb a greater volume of water.
- The test is repeated after students have improved.
- Students evaluate whether their first or second design was more successful. The more water is absorbed, the more successful the design.

Content Extension:

Provide students with a brief description of how they will test their hydroponics systems with actual plants.

Activity (90 min.)

1. Have students remind you of the next step in the engineering design process. (*imagine*) Explain that although imagine is normally individual, this particular lesson has a group activity for the imagine part.
 - Students will examine three materials and discuss their properties: Sponge, paper towel, and diaper
 - Students will test each material to see how much water it can absorb.
 - Students will determine properties that affect how much water a material can absorb.
2. Have students open their notebooks up to the “Imagine” portion. Give each group their set of materials:
 - 3 cups, each containing one of the materials: Sponge, paper towel, and diaper.
 - 1 measuring cup, marked fractions of a cup (1/8, 1/4, 1/2)
3. Give students a few min. to observe the properties of each material by looking at each one and touching it. Then have students share their observations:

Teacher Tip:

Plan ahead for how students will obtain water. Here are some recommended options:

- Assign one person per table to obtain water from the sink to cut down on sink traffic.
- Place a large container of water on each table, where a few pairs of students can reach it, to avoid students walking across the classroom carrying water. (This is also a good option for teachers who do not have a sink in their classroom)

- How thick is each material?
 - Does each material have pores? How large/small are they?
 - Are the materials rough/smooth?
4. Go over the procedures below so students know what to expect during testing and take any questions about the procedures.
 5. The teacher should have a timer. Have the class count down aloud, “3, 2, 1, GO!” and on go:
 - One student in each pair should pour 1 cup of water into the sponge cup.
 - The teacher should sing a song with students while timing 1 min on the timer.
 - The teacher should count down the final 10 seconds aloud, and at zero all students should pour any water not absorbed back into the measuring cup.
 - Assist students in their notebook to determine the volume of absorbed water by subtracting the volume left from the volume added.
 - Have students share the amount of water their sponge absorbed. The teacher can state an estimate most students got close to (i.e. most of the students found that the sponge absorbed about 1/8 cups of water in 1 minute). This amount will be written on the board next to “sponge.”
 6. Repeat procedures in #5 for the cup of paper towel and the cup of the diaper.
 7. Have the class order the materials from least to most absorbent, based on the ranges on the board. Though specific amounts will vary between classes, students should find that:
 - The paper towel is the least absorbent material.
 - The sponge is more absorbent than the paper towel but, less absorbent than the diaper.
 - The diaper is the most absorbent material.
 8. Have students relate each material to its absorbency, and brainstorm which properties may contribute to a materials level of absorbency. (*Observations will vary.*)

Teacher Tip:

If any amounts are very different, those students will share their process and determine why their amount was so different. Relate this to science in real life, how people are different and add another variable that accounts for outlying data (i.e. pouring the water slowly vs. quickly).

9. Have students dispose of and clean up materials from the imagine portion.

10. Ask students which step of the Engineering Design Process is next. (*Plan*) Explain that during this time, students will receive a sample of materials they can choose from to create their designs. They will discuss properties with their group, select materials to use working within their budget, and draw a plan. Explain that these are just samples, so students should not worry about damaging the materials when exploring their properties.

Teaching Tip:

A budget is provided in the advanced engineering notebook using whole dollars. However, the teacher should feel free to make their own budget to meet the needs of their students. Please see prep for alternative budget ideas.

11. Give each group a bag of sample materials and a cup of water (can re-use plastic cups or measuring cups). Provide 10 min for groups to:

- Explore the properties of each material by looking at and touching them. Encourage students to get the materials wet so they can see how this affects the materials' properties, and to see how much water they absorb (not a specific measurement, just squeeze the water back into the container to see if a lot or a little or none comes out).
- Decide which materials they will use and fill in their budget in their notebook.
- Draw how they will use the materials in the planning portion of their notebook.
- Groups who finish planning early can get their plan approved and move onto create.
- The teacher, during this time, should circulate and ask questions such as:
 - How does (material) feel? Rough? Smooth?
 - Does (material) have pores? Are they large or small?
 - Are the properties (material) similar to any of the materials used in the imagine portion (if it was not used in that portion)? What does this tell you about how much water it might absorb?
 - How sturdy is the material dry? Wet? Does this affect whether you will choose this material, or where it will be placed in the filter?
 - What force will be pulling the water down? (*gravity*) How will your design keep materials in the filter from falling into the base due to gravity?

12. After 10 min, let students know it is time to create. Groups who need additional time to plan will cut into their create time, so encourage these groups to wrap up planning as quickly as possible. Each group's plan must be approved before creating. When approving, the teacher should only look to see that students did not exceed their budget, have drawn a plan, and can provide an explanation based on material properties for why they chose these materials. The approval is NOT a judgment on whether a design is "good" or "correct."

13. Give each group whose plan is approved their measuring cup, scissors, a ruler, and their container (retrieve sample materials and water). Students can obtain their materials from

the materials store. Students have 20 min. to create their design. During this time, the teacher should circulate and ask questions such as:

- Is this your original plan, or have you made changes? Why have you made these changes?
- How are you sharing materials and choices with your partner?
- Do you think your design will be successful? Why?
- Do you predict that you will need to improve anything about your design after testing? Why?

14. Provide students with a 10 min, 5 min, 2 min, 1 min, and 30-second warning until testing time. Count down the last 10 seconds. At zero, students should transport their designs to a designated testing zone in the classroom.

- Each group should pour 3 cups of water into the base of their container.
- Students should, at the same time, place the top part, containing their hydroponics system, into the top of the base. Allow the designs to sit for one day.

15. After one day, have students remove the top portion of their container and pour the water from the base into their measuring cup. Students should determine how much water was absorbed and complete the test 1 portion of their notebook.

16. Give students 5 min to make changes to their plan to improve. During this time, students will need to fill out the budget for improve and obtain all new materials. Students cannot reuse materials from their first design so wetness is not a variable in testing absorbency.

17. Once a group's plan for improvement is approved, give students 20 min to make their second design. Students can recreate the original plan with a few changes, or make an entirely new design. During the improve time, the teacher should circulate and ask questions such as:

- What changes have you made to improve your design? What data from test 1 did you base these changes on?
- How are you sharing materials and choices with your partner?
- Do you think your second design will be more successful? Why?
- Do you predict that anything about the first design will be more successful? Why?

18. Provide students with a 10 min, 5 min, 2 min, 1 min, and, 30-second warning until testing time. Count down the last 10 seconds. At zero, students should transport their designs to a designated testing zone in the classroom and follow the same procedures in Test 1.

19. After one day, have students remove the top portion of their container and pour the water from the base into their measuring cup. Students should determine how much water was absorbed and complete the test 2 portion of their notebook.

Reflection (15 min.)

1. Have each group share their design with the rest of the class. Ask the students:
 - Was your second design more successful than your first design? Why or why not?
 - What did different groups' designs have in common? Did any of these commonalities seem to contribute to the success of the designs?
 - How were different groups' designs unique? Did any of these differences seem to contribute to the success of the design?
 - How would you improve your team's design if you had more time?
2. Have students record their thoughts in the reflection portion of their notebooks.

Extension Activity

- The educator can choose a real plant for students to place in their container after two tests. The educator should know the amount of daily water needed for this plant, and make this the target volume for the goal of this lesson. It should be a range, the minimum and maximum water this plant can survive on.
- After completing both tests, the students should alter their container as needed to give the plant access to light and air.
- The educator should take a before picture of each group's plant. Alternatively, if no camera is available have students draw a picture of their plant.
- Have students place the plant in the base of their design. Have students add water to the top portion each day. Determine a length of time to allow the plants to grow inside the container (i.e. a week).
- The educator should take a picture of each group's plant after the designated time. Alternatively, students can draw a picture of their plant.
- Have students compare the properties of their plant before and after sitting in the container to determine how healthy it is.
 - Is the plant healthy? Why or why not?
 - What do the properties of the plant after sitting in the container suggest about how its needs are being met?
- The activity can end there, or the educator can extend it to allow students to improve their containers and let the plant sit in it again to see if they can better meet the needs of the plant.

Board Game Challenge

Prep: 5 – 10 min.

Activity: 65 min.

Science Topic: Engineering and Mathematics

Learning Objectives: Students will...

- Explore how to create a fun and engaging board game using the Engineering Design Process.
- Practice their mathematical skills.

Vocabulary

- two-dimensional shapes
- addition
- subtraction
- multiplication
- measurement

Overview

In this pre-activity, students will use their math skills to create a board game that will move their game pieces from one end of the board to another.

Students must collaborate with their peer(s) to design a board game which will meet their developmentally-appropriate criteria. Students will use developmentally-appropriate measuring tools to determine whether their game has met the criteria, and whether their second prototype has improved in meeting this criteria.

Students work within materials and time constraints as they attempt to solve the problem. Students receive a set number of developmentally-appropriate building materials and create, test, and improve their designs. Students evaluate their designs to determine whether they have met the goal criteria.

Students share their design with their classmates and compare different designs to appreciate the creativity that goes into engineering.

Background

Review content from the section about the Engineering Design Process.

Resources

See resources from the section about the Engineering Design Process.

For more information on the importance of mathematics and developing mathematical skills, see the following;

- <https://www.pbs.org/wgbh/misunderstoodminds/mathbasics.html>

Pre-Requisite Knowledge

Students should have grade-appropriate comprehension of the following concepts:

Basic (students do not necessarily need to be able to do these independently)

- How to measure with a ruler (or with non-standard units of measurements, whichever is the grade level's standard)
- Either the ability to “count on” and “count back” or add and subtract
- Basic two-dimensional shapes
- Comparing greater than, less than, and equal to

Advanced

- How to measure with a ruler to the nearest $\frac{1}{4}$ inch
- Addition, subtraction, and multiplying numbers by a single-digit number

Pre-Requisite Resources: The following resources provide activities for educators who have not yet covered pre-requisite science concepts in the classroom.

Introduction (15 min.)

- I. Review with students what they have learned about measurement and two-dimensional shapes. Ask:
 - **What side of the ruler do we use to measure inches?**
 - **How many inches are in a foot?**
 - **What are the different kinds of shapes?**

2. Expand the discussion of measurement to include centimeters and the difference between two-dimensional and three-dimensional shapes.
3. Ask the students if they have ever played a board game? Allow the students to share their knowledge of the topic. Explain that board games involve rules and methods to follow in order to play the games fairly. Explain to the students that today they are going to be designing their own board games through engineering.
4. Review with students what engineering is. Ask:
 - **What is an engineer?** *(An engineer is a person who uses his or her creativity and knowledge of science and math to design and improve technology to solve problems.)*
 - **What is the process that engineers when they are designing and improving technology?** *(Review each step of the engineering design process. The process should be written on the board or on chart paper for students to see.)*
5. Explain to the students that they are going to be engineers who will be solving a problem using the engineering design process. Tell the students the problem and goal, and write the goal on the board:
 - **Problem:** A toy company needs to create a new fun and engaging board game for four players to be able to play at one time.
 - **Goal:** Design a board game that is both fun and engaging. To be fun, the game board needs to have 30 square spaces measured in centimeters and allow for four players to participate. To be engaging, players must use simple addition and multiplication to move throughout the board.
6. Ask the students: **“Now that we have our goal, where should we start in the engineering design process?”** *(We should ask questions to identify criteria and constraints as well as to explore any science and math content we will need to know to solve the problem.)*
7. Record students’ questions on the board. Make sure the following questions end up on the board:
 - **What materials can we use?**
 - **How do we measure?**
 - **How long will we have to create our designs?**
9. After students have finished brainstorming questions, answer each of them. Record criteria and constraints on the board or on chart paper. Students should record the criteria in the appropriate places in their notebooks.
 - **Measurement:**
 - Students should measure in centimeters consistently to build the game board path.
 - **Mathematics:**

- Number value should be in the ones place.
- Each player should either perform an addition or multiplication problem each turn.
- **Time:** (show the students each corresponding page in their notebooks)
 - Each student will have 5 min. to imagine ideas in their notebooks.
 - Teams will then collaborate for 5 min. to develop a plan.
 - Once the plan has been approved by the teacher, teams will have 15 min. to create their designs. Any changes to the designs should be reflected in the plan.
 - Teams will switch board games to play and test the designs.
 - Teams will then return the boards and have 10 min. to improve their designs.
 - Teams will switch board games again to play and test the improved designs.
- **Materials:** Show the students how to use their grade-appropriate materials. Explain to the students that they will receive a sample of materials to use during their imagining and planning time to experiment with.
 - Each team will receive 4 objects (for game pieces), 1 ruler (with centimeters), 40 index cards, 2 dice, and 4 8 ½" x 11" copy papers.
 - Show students how they can combine the papers to form a larger game board.
 - Demonstrate how to use the ruler to measure and draw the game board.
 - Tell students that one sheet should explain the rules of the game and the other can be used for scrap paper for addition and multiplication.

Activity (45 min.)

1. Have students remind you of the next step in the engineering design process. (*imagine*) Explain that students should be imagining individually and not talking yet. Students will get to share their ideas when it is time to plan.
2. Have students open their notebooks up to the "Imagine" portion. Give each group a sample of their materials. Clarify that these are not part of their building materials, so they don't have to worry about damaging them. Encourage students to experiment with the materials as they imagine ideas. Also, remind students to think about how they will incorporate math in the steps of the game.

Sample materials- give each group:

 - 2 dice
 - 1 index card
 - 1 8 ½" x 11" paper
 - 1 ruler (with centimeters)
3. Give students 5 min. to imagine ideas. Circulate among the students. If students are having trouble imagining ideas, ask them to think about the images of the game boards they saw in class or ones they've seen in real life. Ask:
 - What kinds of shapes did you see on those boards?
 - Were the spaces wide? Short? Tall? Narrow?

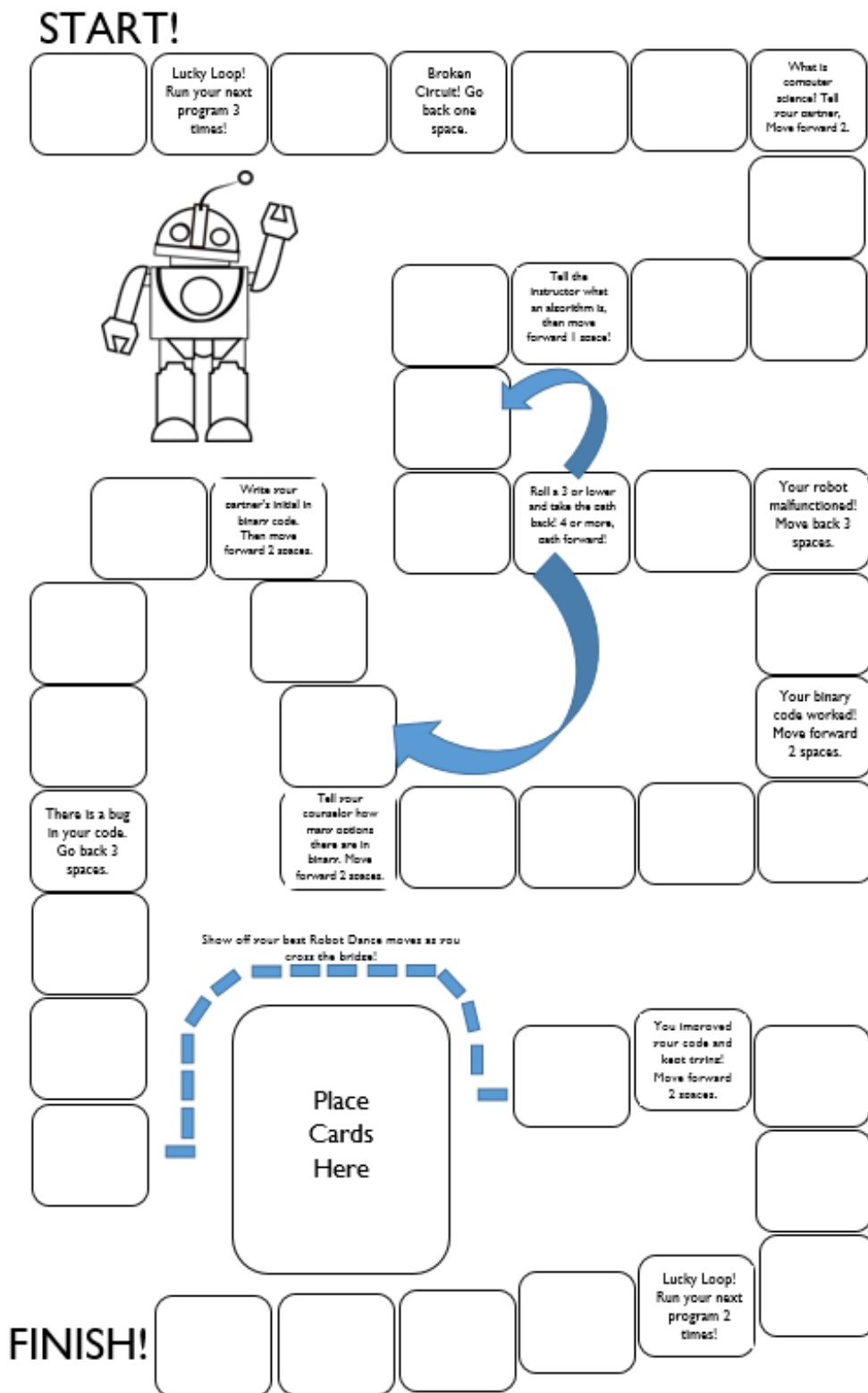
- Were the spaces the same size throughout the whole board?
 - Have you ever designed a game before, even out of different materials? In that past experience, what helped make your game fun?
4. After 5 min., ask the students which step is next in the engineering design process. (*plan*) Set expectations for how students will interact- taking turns, speaking kindly, voting on ideas, etc. Emphasize that groups can combine ideas- they don't just have to choose one. Tell the groups to draw their ideas in their notebooks.
 5. Give students 5 min. to collaborate and form a plan. Circulate during this time, asking students questions:
 - What do you think about _____'s idea?
 - Has everyone gotten a turn to share?
 - What have you seen in real life, or what past experience, makes you think your design will be successful?
 6. After 5 min., check each group's design for approval. Retrieve the sample materials (leave the ruler and 2 dice).
 7. Ask students which step is next in the engineering design process. (*create*) Tell students that they will have 15 min. to create their game boards. Remind students that they can make changes to their design as they build, but that these changes should also be changed in their plan.
 8. Give each group their building materials and set a timer for 15 min. During this time, students should record the process of creating their design in their notebooks, including any changes they've made to their designs. Circulate during this time, asking students questions:
 - How did you come up with this idea?
 - Does your design look like anything you've seen in real life?
 - What sort of changes have you made to your design so far? Why? Have you recorded this in your notebook?
 - Have you recorded what you've done so far in your notebook?
 - Why do you think your design will be successful?
 9. After 15 min., have each team briefly describe their game board, including the rules, with the rest of the class. Then have the teams switch games boards and play another team's design to test. Once tested, have the teams give feedback on the games.
 10. Ask students which step is next in the engineering design process. (*improve*) Tell students that they will have 10 min. to improve their game board. Remind students that they can make changes to their design as they build, but that these changes should also be changed in their plan. Each team can have a new set of paper and index cards if necessary.

11. Set a timer for 10 min. Circulate during this time, asking students questions:
 - What was successful about your design in the first test? What failed in your design in the first test?
 - How are you planning to improve your design based on test results?
 - What sort of changes have you made to your design so far? Why?
 - Have you changed these in your plan as well?
 - Why do you think your improved design will be more successful than your first design?
12. After 10 min., have each team briefly describe their game board again, including the rules, with the rest of the class. Have the teams focus on what they changed or improved. Then have the teams switch games boards and play another team's design to test. Once tested, have the teams give feedback on the games.

Reflection (5 min.)

1. Ask the students:
 - Was your second design more successful than your first design? Why or why not?
 - What did different groups' designs have in common? Did any of these commonalities seem to contribute to the success of the designs?
 - How were different groups' designs unique? Did any of these differences seem to contribute to the success of the design?
 - How would you improve your team's design if you had more time?
2. Have students record their thoughts in the reflection portion of their notebooks.

Example game board and game tasks.



Standards

The following standards are embedded across all of the pre-activities:

K	Science	
	<u>Nature of Science</u>	
	SC.K.N.1.1	Collaborate with a partner to collect information.
	SC.K.N.1.3	Keep records as appropriate -- such as pictorial records -- of investigations conducted.
	SC.K.N.1.2	Make observations of the natural world and know that they are descriptors collected using the five senses.
	SC.K.N.1.4	Observe and create a visual representation of an object which includes its major features.
	SC.K.N.1.5	Recognize that learning can come from careful observation.
	LAFS	
	<u>Standards for Speaking and Listening</u>	
	LAFS.K.SL.1.1	Participate in collaborative conversations with diverse partners about kindergarten topics and texts with peers and adults in small and larger groups.
	LAFS.K.SL.1.2	Confirm understanding of a text read aloud or information presented orally or through other media by asking and answering questions about key details and requesting clarification if something is not understood.

LAFS.K.SL.1.3	Ask and answer questions in order to seek help, get information, or clarify something that is not understood.
LAFS.K.SL.2.5	Add drawings or other visual displays to descriptions as desired to provide additional detail.
LAFS.K.SL.2.6	Speak audibly and express thoughts, feelings, and ideas clearly.
<u>Writing Standards</u>	
LAFS.K.W.1.3	Use a combination of drawing, dictating, and writing to narrate a single event or several loosely linked events, tell about the events in the order in which they occurred, and provide a reaction to what happened.
LAFS.K.W.3.8	With guidance and support from adults, recall information from experiences or gather information from provided sources to answer a question.
MAFS	
<u>Counting and Cardinality</u>	
MAFS.K.CC.1.3	Read and write numerals from 0 to 20. Represent a number of objects with a written numeral 0–20 (with 0 representing a count of no objects).
MAFS.K.CC.2.4	<p>Understand the relationship between numbers and quantities; connect counting to cardinality.</p> <ol style="list-style-type: none"> When counting objects, say the number names in the standard order, pairing each object with one and only one number name and each number name with one and only one object. Understand that the last number name said tells the number of objects counted. The number of objects is the same regardless of their arrangement or the order in which they were counted. Understand that each successive number name refers to a quantity that is one larger.
MAFS.K.CC.3.6	Identify whether the number of objects in one group is greater than, less than, or equal to the number of objects in another group, e.g., by using matching and counting strategies.

	<p><u>Measurement and Data</u></p> <p>MAFS.K.MD.1.2 Directly compare two objects with a measurable attribute in common, to see which object has “more of”/“less of” the attribute, and describe the difference. For example, directly compare the heights of two children and describe one child as taller/shorter.</p>
I	Science
	<u>Nature of Science</u>
	<p>SC.1.N.1.1 Raise questions about the natural world, investigate them in teams through free exploration, and generate appropriate explanations based on those explorations.</p> <p>SC.1.N.1.2 Using the five senses as tools, make careful observations, describe objects in terms of number, shape, texture, size, weight, color, and motion, and compare their observations with others.</p> <p>SC.1.N.1.3 Keep records as appropriate - such as pictorial and written records - of investigations conducted.</p> <p>SC.1.N.1.4 Ask "how do you know?" in appropriate situations.</p>
	LAFS
	<u>Standards for Speaking and Listening</u>
	<p>LAFS.1.SL.1.1 Participate in collaborative conversations with diverse partners about grade I topics and texts with peers and adults in small and larger groups.</p> <p>LAFS.1.SL.1.2 Ask and answer questions about key details in a text read aloud or information presented orally or through other media.</p>

	LAFS.1.SL.1.3	Ask and answer questions about what a speaker says in order to gather additional information or clarify something that is not understood.
	LAFS.1.SL.2.4	Describe people, places, things, and events with relevant details, expressing ideas and feelings clearly.
	LAFS.1.SL.2.5	Add drawings or other visual displays to descriptions when appropriate to clarify ideas, thoughts, and feelings.
	<u>Writing Standards</u>	
	LAFS.1.W.1.3	Write narratives in which they recount two or more appropriately sequenced events, include some details regarding what happened, use temporal words to signal event order, and provide some sense of closure.
	LAFS.1.W.3.8	With guidance and support from adults, recall information from experiences or gather information from provided sources to answer a question.
MAFS		
<u>Operations and Algebraic Thinking</u>		
	MAFS.1.OA.1.1	Use addition and subtraction within 20 to solve word problems involving situations of adding to, taking from, putting together, taking apart, and comparing, with unknowns in all positions, e.g., by using objects, drawings, and equations with a symbol for the unknown number to represent the problem (Students are not required to independently read the word problems.)
2	Science	
	<u>Nature of Science</u>	

SC.2.N.1.1	Raise questions about the natural world, investigate them in teams through free exploration and systematic observations, and generate appropriate explanations based on those explorations.
SC.2.N.1.2	Compare the observations made by different groups using the same tools.
SC.2.N.1.3	Ask "how do you know?" in appropriate situations and attempt reasonable answers when asked the same question by others.
SC.2.N.1.5	Distinguish between empirical observation (what you see, hear, feel, smell, or taste) and ideas or inferences (what you think).
SC.2.N.1.6	Explain how scientists alone or in groups are always investigating new ways to solve problems.
LAFS	
<u>Standards for Speaking and Listening</u>	
LAFS.2.SL.1.1	Participate in collaborative conversations with diverse partners about grade 2 topics and texts with peers and adults in small and larger groups.
LAFS.2.SL.1.3	Ask and answer questions about what a speaker says in order to clarify comprehension, gather additional information, or deepen understanding of a topic or issue.
LAFS.2.SL.2.4	Tell a story or recount an experience with appropriate facts and relevant, descriptive details, speaking audibly in coherent sentences.
<u>Writing Standards</u>	
LAFS.2.W.1.3	Write narratives in which they recount a well-elaborated event or short sequence of events, include details to describe actions, thoughts, and feelings, use temporal words to signal event order, and provide a sense of closure.
LAFS.2.W.3.8	Recall information from experiences or gather information from provided sources to answer a question.

	MAFS	
	<u>Number and Operations in Base Ten</u>	
	MAFS.2.NBT.2.5	Fluently add and subtract within 100 using strategies based on place value, properties of operations, and/or the relationship between addition and subtraction.
3	Science	
	<u>Nature of Science</u>	
	SC.3.N.1.1	Raise questions about the natural world, investigate them individually and in teams through free exploration and systematic investigations, and generate appropriate explanations based on those explorations.
	SC.3.N.1.2	Compare the observations made by different groups using the same tools and seek reasons to explain the differences across groups.
	SC.3.N.1.3	Keep records as appropriate, such as pictorial, written, or simple charts and graphs, of investigations conducted.
	SC.3.N.1.4	Recognize the importance of communication among scientists.
	SC.3.N.1.5	Recognize that scientists question, discuss, and check each others' evidence and explanations.
	SC.3.N.1.6	Infer based on observation.
	SC.3.N.1.7	Explain that empirical evidence is information, such as observations or measurements, that is used to help validate explanations of natural phenomena.
	SC.3.N.3.2	Recognize that scientists use models to help understand and explain how things work.

LAFS	
<u>Standards for Speaking and Listening</u>	
LAFS.3.SL.1.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 3 topics and texts, building on others' ideas and expressing their own clearly.
LAFS.3.SL.1.3	Ask and answer questions about information from a speaker, offering appropriate elaboration and detail.
LAFS.3.SL.2.4	Report on a topic or text, tell a story, or recount an experience with appropriate facts and relevant, descriptive details, speaking clearly at an understandable pace.
<u>Writing Standards</u>	
LAFS.3.W.1.2	Write informative/explanatory texts to examine a topic and convey ideas and information clearly. <ul style="list-style-type: none"> a. Introduce a topic and group related information together; include illustrations when useful to aiding comprehension. b. Develop the topic with facts, definitions, and details. c. Use linking words and phrases (e.g., also, another, and, more, but) to connect ideas within categories of information. d. Provide a concluding statement or section.
LAFS.3.W.3.8	Recall information from experiences or gather information from print and digital sources; take brief notes on sources and sort evidence into provided categories.
MAFS	
<u>Number and Operations with Base Ten</u>	
MAFS.3.NBT.1.2	Fluently add and subtract within 1000 using strategies and algorithms based on place value, properties of operations, and/or the relationship between addition and subtraction.

Science		
4	<u>Nature of Science</u>	
	SC.4.N.1.1	Raise questions about the natural world, use appropriate reference materials that support understanding to obtain information (identifying the source), conduct both individual and team investigations through free exploration and systematic investigations, and generate appropriate explanations based on those explorations.
	SC.4.N.1.2	Compare the observations made by different groups using multiple tools and seek reasons to explain the differences across groups.
	SC.4.N.1.4	Attempt reasonable answers to scientific questions and cite evidence in support.
	SC.4.N.1.5	Compare the methods and results of investigations done by other classmates.
	SC.4.N.1.6	Keep records that describe observations made, carefully distinguishing actual observations from ideas and inferences about the observations.
	SC.4.N.1.7	Recognize and explain that scientists base their explanations on evidence.
LAFS		
	<u>Standards for Speaking and Listening</u>	
	LAFS.4.SL.1.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 4 topics and texts, building on others' ideas and expressing their own clearly.
	LAFS.4.SL.2.4	Report on a topic or text, tell a story, or recount an experience in an organized manner, using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.

	<u>Writing Standards</u>	
	LAFS.4.W.3.7	Conduct short research projects that build knowledge through investigation of different aspects of a topic.
	MAFS	
	<u>Number and Operations in Base Ten</u>	
	MAFS.4.NBT.2.5	Multiply a whole number of up to four digits by a one-digit whole number, and multiply two two-digit numbers, using strategies based on place value and the properties of operations. Illustrate and explain the calculation by using equations, rectangular arrays, and/or area models.
5	Science	
	<u>Nature of Science</u>	
	SC.5.N.1.1	Define a problem, use appropriate reference materials to support scientific understanding, plan and carry out scientific investigations of various types such as: systematic observations, experiments requiring the identification of variables, collecting and organizing data, interpreting data in charts, tables, and graphics, analyze information, make predictions, and defend conclusions.
	SC.5.N.2.1	Recognize and explain that science is grounded in empirical observations that are testable; explanation must always be linked with evidence.
	SC.5.N.2.2	Recognize and explain that when scientific investigations are carried out, the evidence produced by those investigations should be replicable by others.
	LAFS	
	<u>Standards for Speaking and Listening</u>	

LAFS.5.SL.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 5 topics and texts, building on others' ideas and expressing their own clearly.
LAFS.5.SL.2.4	Report on a topic or text or present an opinion, sequencing ideas logically and using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.
<u>Writing Standards</u>	
LAFS.5.W.3.7	Conduct short research projects that use several sources to build knowledge through investigation of different aspects of a topic.
MAFS	
<u>Number and Operations in Base Ten</u>	
MAFS.5.NBT.1.4	Use place value understanding to round decimals to any place.
MAFS.5.NBT.2.7	Add, subtract, multiply, and divide decimals to hundredths, using concrete models or drawings and strategies based on place value, properties of operations, and/or the relationship between addition and subtraction; relate the strategy to a written method and explain the reasoning used.
<u>Operations and Algebraic Thinking</u>	
MAFS.5.OA.1.2	Write simple expressions that record calculations with numbers, and interpret numerical expressions without evaluating them.
<u>Measurement and Data</u>	
MAFS.5.MD.1.1	Convert among different-sized standard measurement units (i.e., km, m, cm; kg, g; lb, oz.; l, ml; hr, min, sec) within a given measurement system (e.g., convert 5 cm to 0.05 m), and use these conversions in solving multi-step, real world problems.

The following standards are embedded in each of the pre-activities:

Scaffolding System		
K	Science	
	<u>Earth and Space</u>	
	SC.K.E.5.1	Explore the Law of Gravity by investigating how objects are pulled toward the ground unless something holds them up.
	<u>Physical Science</u>	
	SC.K.P.9.1	Recognize that the shape of materials such as paper and clay can be changed by cutting, tearing, crumpling, smashing, or rolling.
	SC.K.P.13.1	Observe that a push or a pull can change the way an object is moving.
	MAFS	
	<u>Geometry</u>	
	MAFS.K.G.1.2	Correctly name shapes regardless of their orientations or overall size.
	MAFS.K.G.1.3	Identify shapes as two-dimensional (lying in a plane, “flat”) or three-dimensional (“solid”).
	MAFS.K.G.2.4	Analyze and compare two- and three-dimensional shapes, in different sizes and orientations, using informal language to describe their similarities, differences, parts (e.g., number of sides and vertices/“corners”) and other attributes (e.g., having sides of equal length).
	MAFS.K.G.2.5	Model shapes in the world by building shapes from components (e.g., sticks and clay balls) and drawing shapes.

	MAFS.K.G.2.6	Compose simple shapes to form larger shapes. For example, “Can you join these two triangles with full sides touching to make a rectangle?”
	<u>Measurement and Data</u>	
	MAFS.K.MD.1.a	Express the length of an object as a whole number of length units, by laying multiple copies of a shorter object (the length unit) end to end; understand that the length measurement of an object is the number of same-size length units that span it with no gaps or overlaps. Limit to contexts where the object being measured is spanned by a whole number of length units with no gaps or overlaps.
	<u>Operations and Algebraic Thinking</u>	
	MAFS.K.OA.1.1	Represent addition and subtraction with objects, fingers, mental images, drawings, sounds (e.g., claps), acting out situations, verbal explanations, expressions, or equations.
I	Science	
	<u>Earth and Space</u>	
	SC.1.E.5.2	Explore the Law of Gravity by demonstrating that Earth's gravity pulls any object on or near Earth toward it even though nothing is touching the object.
	<u>Physical Science</u>	
	SC.1.P.13.1	Demonstrate that the way to change the motion of an object is by applying a push or a pull.
	MAFS	
	<u>Geometry</u>	

	MAFS.1.G.1.2	Compose two-dimensional shapes (rectangles, squares, trapezoids, triangles, half-circles, and quarter-circles) or three-dimensional shapes (cubes, right rectangular prisms, right circular cones, and right circular cylinders) to create a composite shape, and compose new shapes from the composite shape.
	<u>Measurement and Data</u>	
	MAFS.1.MD.1.a	Understand how to use a ruler to measure length to the nearest inch. a. Recognize that the ruler is a tool that can be used to measure the attribute of length. b. Understand the importance of the zero point and end point and that the length measure is the span between two points. c. Recognize that the units marked on a ruler have equal length intervals and fit together with no gaps or overlaps. These equal interval distances can be counted to determine the overall length of an object.
	<u>Understand Place Value</u>	
	MAFS.1.NBT.2.3	Compare two two-digit numbers based on meanings of the tens and ones digits, recording the results of comparisons with the symbols $>$, $=$, and $<$.
Science		
2	<u>Physical Science</u>	
	SC.2.P.13.1	Investigate the effect of applying various pushes and pulls on different objects.
	SC.2.P.13.3	Recognize that objects are pulled toward the ground unless something holds them up.
	SC.2.P.13.4	Demonstrate that the greater the force (push or pull) applied to an object, the greater the change in motion of the object.
MAFS		

	<u>Geometry</u>
	MAFS.2.G.1.1 Recognize and draw shapes having specified attributes, such as a given number of angles or a given number of equal faces. Identify triangles, quadrilaterals, pentagons, hexagons, and cubes.
	<u>Measurement and Data</u>
	MAFS.2.MD.1.1 Measure the length of an object to the nearest inch, foot, centimeter, or meter by selecting and using appropriate tools such as rulers, yardsticks, meter sticks, and measuring tapes.
	MAFS.2.MD.1.4 Measure to determine how much longer one object is than another, expressing the length difference in terms of a standard length unit.
	MAFS.2.MD.2.5 Use addition and subtraction within 100 to solve word problems involving lengths that are given in the same units, e.g., by using drawings (such as drawings of rulers) and equations with a symbol for the unknown number to represent the problem.
	MAFS.2.MD.4.10 Draw a picture graph and a bar graph (with single-unit scale) to represent a data set with up to four categories. Solve simple put-together, take-apart, and compare problems using information presented in a bar graph.
	<u>Operations and Algebraic Thinking</u>
3	MAFS.2.OA.1.1 Use addition and subtraction within 100 to solve one- and two-step word problems involving situations of adding to, taking from, putting together, taking apart, and comparing, with unknowns in all positions, e.g., by using drawings and equations with a symbol for the unknown number to represent the problem.
	Science
	<u>Earth and Space</u>

SC.3.E.5.4	Explore the Law of Gravity by demonstrating that gravity is a force that can be overcome.
<u>Physical Science</u>	
SC.3.P.10.2	Recognize that energy has the ability to cause motion or create change.
MAFS	
<u>Geometry</u>	
MAFS.3.G.1.1	Understand that shapes in different categories (e.g., rhombuses, rectangles, and others) may share attributes (e.g., having four sides), and that the shared attributes can define a larger category (e.g., quadrilaterals). Recognize rhombuses, rectangles, and squares as examples of quadrilaterals, and draw examples of quadrilaterals that do not belong to any of these subcategories.
<u>Measurement and Data</u>	
MAFS.3.MD.1.2	Measure and estimate liquid volumes and masses of objects using standard units of grams (g), kilograms (kg), and liters (l). Add, subtract, multiply, or divide to solve one-step word problems involving masses or volumes that are given in the same units.
MAFS.3.MD.2.3	Draw a scaled picture graph and a scaled bar graph to represent a data set with several categories. Solve one- and two-step “how many more” and “how many less” problems using information presented in scaled bar graphs.
MAFS.3.MD.2.4	Generate measurement data by measuring lengths using rulers marked with halves and fourths of an inch. Show the data by making a line plot, where the horizontal scale is marked off in appropriate units—whole numbers, halves, or quarters.
MAFS.3.MD.3.7	Relate area to the operations of multiplication and addition. a. Find the area of a rectangle with whole-number side lengths by tiling it, and show that the area is the same as would be found by multiplying the side lengths.

	<p>MAFS.3.MD.4.8 Solve real world and mathematical problems involving perimeters of polygons, including finding the perimeter given the side lengths, finding an unknown side length, and exhibiting rectangles with the same perimeter and different areas or with the same area and different perimeters.</p> <p><u>Operations and Algebraic Thinking</u></p> <p>MAFS.3.OA.1.1 Interpret products of whole numbers, e.g., interpret 5×7 as the total number of objects in 5 groups of 7 objects each.</p>
	Science
	<u>Physical Science</u>
	<p>SC.4.P.10.2 Investigate and describe that energy has the ability to cause motion or create change.</p> <p>SC.4.P.8.3 Explore the Law of Conservation of Mass by demonstrating that the mass of a whole object is always the same as the sum of the masses of its parts.</p>
	MAFS
4	<p><u>Measurement and Data</u></p> <p>MAFS.4.MD.1.2 Use the four operations to solve word problems involving distances, intervals of time, and money, including problems involving simple fractions or decimals. Represent fractional quantities of distance and intervals of time using linear models.</p> <p>MAFS.4.MD.1.3 Apply the area and perimeter formulas for rectangles in real world and mathematical problems.</p> <p>MAFS.4.MD.2.4 Make a line plot to display a data set of measurements in fractions of a unit ($\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$). Solve problems involving addition and subtraction of fractions by using information presented in line plots.</p> <p><u>Number and Operations in Base Ten</u></p>

	MAFS.4.NBT.2.5	Multiply a whole number of up to four digits by a one-digit whole number, and multiply two two-digit numbers, using strategies based on place value and the properties of operations. Illustrate and explain the calculation by using equations, rectangular arrays, and/or area models.
Science		
<u>Physical Science</u>		
5	SC.5.P.10.2	Investigate and explain that energy has the ability to cause motion or create change.
	SC.5.P.13.1	Identify familiar forces that cause objects to move, such as pushes or pulls, including gravity acting on falling objects.
	SC.5.P.13.2	Investigate and describe that the greater the force applied to it, the greater the change in motion of a given object.
	SC.5.P.13.3	Investigate and describe that the more mass an object has, the less effect a given force will have on the object's motion.
	SC.5.P.13.4	Investigate and explain that when a force is applied to an object but it does not move, it is because another opposing force is being applied by something in the environment so that the forces are balanced.
MAFS		
<u>Measurement and Data</u>		
	MAFS.5.G.2.3	Understand that attributes belonging to a category of two-dimensional figures also belong to all subcategories of that category.
<u>Number and Operations in Base Ten</u>		

	MAFS.5.NBT.2.5	Fluently multiply multi-digit whole numbers using the standard algorithm.
--	----------------	---

Design a Roller Coaster		
K	Science	
	<u>Earth and Space</u>	
	SC.K.E.5.1	Explore the Law of Gravity by investigating how objects are pulled toward the ground unless something holds them up.
	<u>Physical Science</u>	
	SC.K.P.12.1	Investigate that things move in different ways, such as fast, slow, etc.
	SC.K.P.13.1	Observe that a push or a pull can change the way an object is moving.
	MAFS	
	<u>Operations and Algebraic Thinking</u>	
	MAFS.K.OA.1.1	Represent addition and subtraction with objects, fingers, mental images, drawings, sounds (e.g., claps), acting out situations, verbal explanations, expressions, or equations.
I	Science	
	<u>Earth and Space</u>	
	SC.I.E.5.2	Explore the Law of Gravity by demonstrating that Earth's gravity pulls any object on or near Earth toward it even though nothing is touching the object.

	<u>Physical Science</u>	
	SC.1.P.12.1	Demonstrate and describe the various ways that objects can move, such as in a straight line, zigzag, back-and-forth, round-and-round, fast, and slow.
	SC.1.P.13.1	Demonstrate that the way to change the motion of an object is by applying a push or a pull.
	MAFS	
	<u>Measurement and Data</u>	
2	MAFS.2.MD.1.1	Measure the length of an object to the nearest inch, foot, centimeter, or meter by selecting and using appropriate tools such as rulers, yardsticks, meter sticks, and measuring tapes.
	MAFS.2.MD.1.4	Measure to determine how much longer one object is than another, expressing the length difference in terms of a standard length unit.
	Science	
	<u>Physical Science</u>	
	SC.2.P.13.1	Investigate the effect of applying various pushes and pulls on different objects.
	SC.2.P.13.3	Recognize that objects are pulled toward the ground unless something holds them up.
	SC.2.P.13.4	Demonstrate that the greater the force (push or pull) applied to an object, the greater the change in motion of the object.
	MAFS	
	<u>Measurement and Data</u>	

	MAFS.2.MD.1.1	Measure the length of an object to the nearest inch, foot, centimeter, or meter by selecting and using appropriate tools such as rulers, yardsticks, meter sticks, and measuring tapes.
	MAFS.2.MD.1.4	Measure to determine how much longer one object is than another, expressing the length difference in terms of a standard length unit.
3	Science	
	<u>Earth and Space</u>	
	SC.3.E.5.4	Explore the Law of Gravity by demonstrating that gravity is a force that can be overcome.
	<u>Physical Science</u>	
	SC.3.P.10.2	Recognize that energy has the ability to cause motion or create change.
	SC.3.P.11.2	Investigate, observe, and explain that heat is produced when one object rubs against another, such as rubbing one's hands together.
	MAFS	
	<u>Measurement and Data</u>	
	MAFS.3.MD.2.3	Draw a scaled picture graph and a scaled bar graph to represent a data set with several categories. Solve one- and two-step “how many more” and “how many less” problems using information presented in scaled bar graphs.
	MAFS.3.MD.2.4	Generate measurement data by measuring lengths using rulers marked with halves and fourths of an inch. Show the data by making a line plot, where the horizontal scale is marked off in appropriate units—whole numbers, halves, or quarters.
	<u>Operations and Algebraic Thinking</u>	

	MAFS.3.OA.1.2	Interpret whole-number quotients of whole numbers, e.g., interpret $56 \div 8$ as the number of objects in each share when 56 objects are partitioned equally into 8 shares, or as a number of shares when 56 objects are partitioned into equal shares of 8 objects each.
4	Science	
	<u>Physical Science</u>	
	SC.4.P.10.1	Observe and describe some basic forms of energy, including light, heat, sound, electrical, and the energy of motion.
	SC.4.P.10.2	Investigate and describe that energy has the ability to cause motion or create change.
	SC.4.P.12.1	Recognize that an object in motion always changes its position and may change its direction.
	SC.4.P.12.2	Investigate and describe that the speed of an object is determined by the distance it travels in a unit of time and that objects can move at different speeds.
	MAFS	
	<u>Measurement and Data</u>	
	MAFS.4.MD.1.2	Use the four operations to solve word problems involving distances, intervals of time, and money, including problems involving simple fractions or decimals. Represent fractional quantities of distance and intervals of time using linear models.
	<u>Number and Operations in Base Ten</u>	

	MAFS.4.NBT.1.2	Read and write multi-digit whole numbers using base-ten numerals, number names, and expanded form. Compare two multi-digit numbers based on meanings of the digits in each place, using $>$, $=$, and $<$ symbols to record the results of comparisons.
	MAFS.4.NBT.2.6	Find whole-number quotients and remainders with up to four-digit dividends and one-digit divisors, using strategies based on place value, the properties of operations, and/or the relationship between multiplication and division. Illustrate and explain the calculation by using equations, rectangular arrays, and/or area models.
Science		
5	<u>Physical Science</u>	
	SC.5.P.10.2	Investigate and explain that energy has the ability to cause motion or create change.
	SC.5.P.13.1	Identify familiar forces that cause objects to move, such as pushes or pulls, including gravity acting on falling objects.
	SC.5.P.13.2	Investigate and describe that the greater the force applied to it, the greater the change in motion of a given object.
	SC.5.P.13.3	Investigate and describe that the more mass an object has, the less effect a given force will have on the object's motion.
	SC.5.P.13.4	Investigate and explain that when a force is applied to an object but it does not move, it is because another opposing force is being applied by something in the environment so that the forces are balanced.
Mathematics		
	<u>Numbers and Operations in Base Ten</u>	
	MAFS.5.NBT.2.5	Fluently multiply multi-digit whole numbers using the standard algorithm.

	<p>MAFS.5.NBT.2.6 Find whole-number quotients of whole numbers with up to four-digit dividends and two-digit divisors, using strategies based on place value, the properties of operations, and/or the relationship between multiplication and division. Illustrate and explain the calculation by using equations, rectangular arrays, and/or area models.</p>
--	--

Designing Play Dough	
K	Science
	<u>Physical Science</u>
	<p>SC.K.P.8.1 Sort objects by observable properties, such as size, shape, color, temperature (hot or cold), weight (heavy or light) and texture.</p>
	<p>SC.K.P.9.1 Recognize that the shape of materials such as paper and clay can be changed by cutting, tearing, crumpling, smashing, or rolling.</p>
	MAFS
	<u>Operations and Algebraic Thinking</u>
	<p>MAFS.K.OA.1.1 Represent addition and subtraction with objects, fingers, mental images, drawings, sounds (e.g., claps), acting out situations, verbal explanations, expressions, or equations.</p>
	<p>MAFS.K.OA.1.2 Solve addition and subtraction word problems, and add and subtract within 10, e.g., by using objects or drawings to represent the problem (Students are not required to independently read the word problems.)</p>
I	Science

	<u>Physical Science</u>	
	SC.1.P.8.1	Sort objects by observable properties, such as size, shape, color, temperature (hot or cold), weight (heavy or light), texture, and whether objects sink or float.
	MAFS	
	<u>Operations and Algebraic Thinking</u>	
	MAFS.1.OA.1.1	Use addition and subtraction within 20 to solve word problems involving situations of adding to, taking from, putting together, taking apart, and comparing, with unknowns in all positions, e.g., by using objects, drawings, and equations with a symbol for the unknown number to represent the problem (Students are not required to independently read the word problems.)
2	MAFS.1.OA.1.2	Solve word problems that call for addition of three whole numbers whose sum is less than or equal to 20, e.g., by using objects, drawings, and equations with a symbol for the unknown number to represent the problem.
	MAFS.1.OA.3.5	Relate counting to addition and subtraction (e.g., by counting on 2 to add 2).
	Science	
	<u>Physical Science</u>	
	SC.2.P.8.1	Observe and measure objects in terms of their properties, including size, shape, color, temperature, weight, texture, sinking or floating in water, and attraction and repulsion of magnets.
	SC.2.P.8.2	Identify objects and materials as solid, liquid, or gas.
	SC.2.P.8.3	Recognize that solids have a definite shape and that liquids and gases take the shape of their container.

	SC.2.P.9.1	Investigate that materials can be altered to change some of their properties, but not all materials respond the same way to any one alteration.
	MAFS	
	<u>Operations and Algebraic Thinking</u>	
	MAFS.2.OA.2.2	Fluently add and subtract within 20 using mental strategies. By end of Grade 2, know from memory all sums of two one-digit numbers.
3	Science	
	<u>Physical Science</u>	
	SC.3.P.8.2	Measure and compare the mass and volume of solids and liquids.
	SC.3.P.8.3	Compare materials and objects according to properties such as size, shape, color, texture, and hardness.
	MAFS	
	MAFS.3.MD.1.2	Measure and estimate liquid volumes and masses of objects using standard units of grams (g), kilograms (kg), and liters (l). Add, subtract, multiply, or divide to solve one-step word problems involving masses or volumes that are given in the same units.
	MAFS.3.NF.1.1	Understand a fraction $\frac{1}{b}$ as the quantity formed by 1 part when a whole is partitioned into b equal parts; understand a fraction $\frac{a}{b}$ as the quantity formed by a parts of size $\frac{1}{b}$.
4	MAFS.3.NF.1.3	Explain equivalence of fractions in special cases, and compare fractions by reasoning about their size.
	Science	

	<u>Physical Science</u>	
	SC.4.P.8.1	Measure and compare objects and materials based on their physical properties including: mass, shape, volume, color, hardness, texture, odor, taste, attraction to magnets.
	MAFS	
	<u>Number and Operations- Fractions</u>	
	MAFS.4.NF.1.2	Compare two fractions with different numerators and different denominators, e.g., by creating common denominators or numerators, or by comparing to a benchmark fraction such as $\frac{1}{2}$. Recognize that comparisons are valid only when the two fractions refer to the same whole. Record the results of comparisons with symbols $>$, $=$, or $<$, and justify the conclusions, e.g., by using a visual fraction model.
5	Science	
	<u>Physical Science</u>	
	SC.5.P.8.1	Compare and contrast the basic properties of solids, liquids, and gases, such as mass, volume, color, texture, and temperature.
	SC.5.P.8.2	Investigate and identify materials that will dissolve in water and those that will not and identify the conditions that will speed up or slow down the dissolving process.
	SC.5.P.8.3	Demonstrate and explain that mixtures of solids can be separated based on observable properties of their parts such as particle size, shape, color, and magnetic attraction.
	SC.5.P.8.4	Explore the scientific theory of atoms (also called atomic theory) by recognizing that all matter is composed of parts that are too small to be seen without magnification.
	SC.5.P.9.1	Investigate and describe that many physical and chemical changes are affected by temperature.

MAFS	
<u>Measurement and Data</u>	
MAFS.5.MD.3.3	Recognize volume as an attribute of solid figures and understand concepts of volume measurement.
MAFS.5.MD.3.5	Relate volume to the operations of multiplication and addition and solve real world and mathematical problems involving volume.
<u>Numbers and Operation in Base Ten</u>	
MAFS.5.NBT.2.5	Fluently multiply multi-digit whole numbers using the standard algorithm.
MAFS.5.NBT.2.6	Find whole-number quotients of whole numbers with up to four-digit dividends and two-digit divisors, using strategies based on place value, the properties of operations, and/or the relationship between multiplication and division. Illustrate and explain the calculation by using equations, rectangular arrays, and/or area models.
<u>Numbers and Operations- Fractions</u>	
MAFS.5.NF.1.1	Add and subtract fractions with unlike denominators (including mixed numbers) by replacing given fractions with equivalent fractions in such a way as to produce an equivalent sum or difference of fractions with like denominators.
MAFS.5.NF.1.2	Solve word problems involving addition and subtraction of fractions referring to the same whole, including cases of unlike denominators, e.g., by using visual fraction models or equations to represent the problem. Use benchmark fractions and number sense of fractions to estimate mentally and assess the reasonableness of answers.

Runoff Reduction System	
	Science

K	<u>Earth and Space Science</u>	
	SC.K.E.5.1	Explore the Law of Gravity by investigating how objects are pulled toward the ground unless something holds them up.
	MAFS	
	<u>Measurement and Data</u>	
	MAFS.K.MD.1.a	Express the length of an object as a whole number of length units, by laying multiple copies of a shorter object (the length unit) end to end; understand that the length measurement of an object is the number of same-size length units that span it with no gaps or overlaps.
I	Science	
	<u>Earth and Space Science</u>	
	SC.1.E.6.1	Recognize that water, rocks, soil, and living organisms are found on Earth's surface.
	SC.1.E.6.2	Describe the need for water and how to be safe around water.
	<u>Life Science</u>	
	SC.1.L.17.1	Through observation, recognize that all plants and animals, including humans, need the basic necessities of air, water, food, and space.
	MAFS	
	<u>Measurement and Data</u>	
	MAFS.1.MD.1.a	Understand how to use a ruler to measure length to the nearest inch.

	Science
	<u>Earth and Space Science</u>
	SC.2.E.7.1 Compare and describe changing patterns in nature that repeat themselves, such as weather conditions including temperature and precipitation, day to day and season to season.
	SC.2.E.7.5 State the importance of preparing for severe weather, lightning, and other weather related events.
	<u>Life Science</u>
2	SC.2.L.17.2 Recognize and explain that living things are found all over Earth, but each is only able to live in habitats that meet its basic needs.
	MAFS
	<u>Measurement and Data</u>
	MAFS.2.MD.1.1 Measure the length of an object to the nearest inch, foot, centimeter, or meter by selecting and using appropriate tools such as rulers, yardsticks, meter sticks, and measuring tapes.
	MAFS.2.MD.1.4 Measure to determine how much longer one object is than another, expressing the length difference in terms of a standard length unit.
	Science
3	<u>Earth and Space Science</u>
	SC.3.E.5.4 Explore the Law of Gravity by demonstrating that gravity is a force that can be overcome.

	MAFS	
	<u>Measurement and Data</u>	
	MAFS.3.MD.2.3	Draw a scaled picture graph and a scaled bar graph to represent a data set with several categories. Solve one- and two-step “how many more” and “how many less” problems using information presented in scaled bar graphs.
	MAFS.3.MD.2.4	Generate measurement data by measuring lengths using rulers marked with halves and fourths of an inch. Show the data by making a line plot, where the horizontal scale is marked off in appropriate units—whole numbers, halves, or quarters.
4	Science	
	<u>Earth and Space Science</u>	
	SC.4.E.6.3	Recognize that humans need resources found on Earth and that these are either renewable or nonrenewable.
	SC.4.E.6.4	Describe the basic differences between physical weathering (breaking down of rock by wind, water, ice, temperature change, and plants) and erosion (movement of rock by gravity, wind, water, and ice).
	SC.4.E.6.6	Identify resources available in Florida (water, phosphate, oil, limestone, silicon, wind, and solar energy).
	<u>Life Science</u>	
	SC.4.L.17.4	Recognize ways plants and animals, including humans, can impact the environment.
	MAFS	
	<u>Measurement and Data</u>	

	MAFS.4.MD.1.2	Use the four operations to solve word problems involving distances, intervals of time, and money, including problems involving simple fractions or decimals. Represent fractional quantities of distance and intervals of time using linear models.
5	Science	
	<u>Physical Science</u>	
	SC.5.P.13.1	Identify familiar forces that cause objects to move, such as pushes or pulls, including gravity acting on falling objects.
	SC.5.P.13.2	Investigate and describe that the greater the force applied to it, the greater the change in motion of a given object.
	SC.5.P.13.4	Investigate and explain that when a force is applied to an object but it does not move, it is because another opposing force is being applied by something in the environment so that the forces are balanced.
	<u>Earth and Space Science</u>	
	SC.5.E.7.1	Create a model to explain the parts of the water cycle. Water can be a gas, a liquid, or a solid and can go back and forth from one state to another.
	SC.5.E.7.2	Recognize that the ocean is an integral part of the water cycle and is connected to all of Earth's water reservoirs via evaporation and precipitation processes.
	SC.5.E.7.4	Distinguish among the various forms of precipitation (rain, snow, sleet, and hail), making connections to the weather in a particular place and time.
	MAFS	
	<u>Numbers and Operation in Base Ten</u>	

	MAFS.5.NBT.2.5	Fluently multiply multi-digit whole numbers using the standard algorithm.
--	----------------	---

Create a Zip Line		
Science		
See standards embedded across all of the pre-activities		
K	MAFS	
	<u>Measurement and Data</u>	
	MAFS.K.MD.1.a	Express the length of an object as a whole number of length units, by laying multiple copies of a shorter object (the length unit) end to end; understand that the length measurement of an object is the number of same-size length units that span it with no gaps or overlaps.
1	MAFS	
	<u>Measurement and Data</u>	
	MAFS.1.MD.1.a	Understand how to use a ruler to measure length to the nearest inch.
2	MAFS	
	<u>Measurement and Data</u>	
	MAFS.2.MD.1.1	Measure the length of an object to the nearest inch, foot, centimeter, or meter by selecting and using appropriate tools such as rulers, yardsticks, meter sticks, and measuring tapes.
	MAFS.2.MD.1.4	Measure to determine how much longer one object is than another, expressing the length difference in terms of a standard length unit.

MAFS		
3	<u>Measurement and Data</u>	
	MAFS.3.MD.2.4	Generate measurement data by measuring lengths using rulers marked with halves and fourths of an inch. Show the data by making a line plot, where the horizontal scale is marked off in appropriate units—whole numbers, halves, or quarters.
MAFS		
4	<u>Measurement and Data</u>	
	MAFS.4.MD.1.2	Use the four operations to solve word problems involving distances, intervals of time, and money, including problems involving simple fractions or decimals. Represent fractional quantities of distance and intervals of time using linear models.
	MAFS.4.MD.2.4	Make a line plot to display a data set of measurements in fractions of a unit ($\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$). Solve problems involving addition and subtraction of fractions by using information presented in line plots.
MAFS		
5	<u>Measurement and Data</u>	
	MAFS.5.MD.2.2	Make a line plot to display a data set of measurements in fractions of a unit ($\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$). Use operations on fractions for this grade to solve problems involving information presented in line plots.
	MAFS.5.NF.1.2	Solve word problems involving addition and subtraction of fractions referring to the same whole, including cases of unlike denominators, e.g., by using visual fraction models or equations to represent the

	problem. Use benchmark fractions and number sense of fractions to estimate mentally and assess the reasonableness of answers.
--	---

Design a Paper Copter		
K	Science	
	<u>Earth and Space</u>	
	SC.K.E.5.1	Explore the Law of Gravity by investigating how objects are pulled toward the ground unless something holds them up.
	<u>Physical Science</u>	
	SC.K.P.12.1	Investigate that things move in different ways, such as fast, slow, etc.
	SC.K.P.8.1	Sort objects by observable properties, such as size, shape, color, temperature (hot or cold), weight (heavy or light) and texture.
	MAFS	
	<u>Geometry</u>	
	MAFS.K.G.1.2	Correctly name shapes regardless of their orientations or overall size.
	MAFS.K.G.2.4	Analyze and compare two- and three-dimensional shapes, in different sizes and orientations, using informal language to describe their similarities, differences, parts (e.g., number of sides and vertices/corners) and other attributes (e.g., having sides of equal length).

I	Science	
	<u>Earth and Space</u>	
	SC.1.E.5.2	Explore the Law of Gravity by demonstrating that Earth's gravity pulls any object on or near Earth toward it even though nothing is touching the object.
	<u>Physical Science</u>	
	SC.1.P.12.1	Demonstrate and describe the various ways that objects can move, such as in a straight line, zigzag, back-and-forth, round-and-round, fast, and slow.
	SC.1.P.8.1	Sort objects by observable properties, such as size, shape, color, temperature (hot or cold), weight (heavy or light), texture, and whether objects sink or float.
	MAFS	
	<u>Geometry</u>	
	MAFS.1.G.1.1	Distinguish between defining attributes (e.g., triangles are closed and three-sided) versus non-defining attributes (e.g., color, orientation, overall size); build and draw shapes to possess defining attributes.
	<u>Measurement and Data</u>	
	MAFS.1.MD.1.a	Understand how to use a ruler to measure length to the nearest inch. Recognize that the ruler is a tool that can be used to measure the attribute of length. Understand the importance of the zero point and end point and that the length measure is the span between two points. Recognize that the units marked on a ruler have equal length intervals and fit together with no gaps or overlaps. These equal interval distances can be counted to determine the overall length of an object.

	MAFS.1.MD.3.4	Organize, represent, and interpret data with up to three categories; ask and answer questions about the total number of data points, how many in each category, and how many more or less are in one category than in another.
2	Science	
	<u>Physical Science</u>	
	SC.2.P.13.3	Recognize that objects are pulled toward the ground unless something holds them up.
	SC.2.P.8.1	Observe and measure objects in terms of their properties, including size, shape, color, temperature, weight, texture, sinking or floating in water, and attraction and repulsion of magnets.
	MAFS	
	<u>Measurement and Data</u>	
	MAFS.2.MD.1.1	Measure the length of an object to the nearest inch, foot, centimeter, or meter by selecting and using appropriate tools such as rulers, yardsticks, meter sticks, and measuring tapes.
	MAFS.2.MD.1.4	Measure to determine how much longer one object is than another, expressing the length difference in terms of a standard length unit.
	MAFS.2.MD.4.10	Draw a picture graph and a bar graph (with single-unit scale) to represent a data set with up to four categories. Solve simple put-together, take-apart, and compare problems using information presented in a bar graph.

3	Science	
	<u>Earth and Space</u>	
	SC.3.E.5.4	Explore the Law of Gravity by demonstrating that gravity is a force that can be overcome.
	<u>Physical Science</u>	
	SC.3.P.10.2	Recognize that energy has the ability to cause motion or create change.
	SC.3.P.8.3	Compare materials and objects according to properties such as size, shape, color, texture, and hardness.
	MAFS	
	<u>Measurement and Data</u>	
	MAFS.3.MD.3.5	Recognize area as an attribute of plane figures and understand concepts of area measurement. A square with side length 1 unit, called a unit square, is said to have one square unit of area, and can be used to measure area. A plane figure which can be covered without gaps or overlaps by n unit squares is said to have an area of n square units.
	MAFS.3.MD.3.7	Relate area to the operations of multiplication and addition. Find the area of a rectangle with whole-number side lengths by tiling it, and show that the area is the same as would be found by multiplying the side lengths. Multiply side lengths to find areas of rectangles with whole-number side lengths in the context of solving real world and mathematical problems, and represent whole-number products as rectangular areas in mathematical reasoning. Use tiling to show in a concrete case that the area of a rectangle with whole-number side lengths a and $b + c$ is the sum of a and $a \cdot c$. Use area models to represent the distributive property in mathematical reasoning. Recognize area as additive. Find areas of rectilinear figures by decomposing them into non-overlapping rectangles and adding the areas of the non-overlapping parts, applying this technique to solve real world problems.
	<u>Operations and Algebraic Thinking</u>	

	MAFS.3.OA.3.7	Fluently multiply and divide within 100, using strategies such as the relationship between multiplication and division (e.g., knowing that $8 \times 5 = 40$, one knows $40 \div 5 = 8$) or properties of operations. By the end of Grade 3, know from memory all products of two one-digit numbers.
4	Science	
	<u>Physical Science</u>	
	SC.4.P.10.1	Observe and describe some basic forms of energy, including light, heat, sound, electrical, and the energy of motion.
	SC.4.P.12.1	Recognize that an object in motion always changes its position and may change its direction.
	SC.4.P.8.1	Measure and compare objects and materials based on their physical properties including: mass, shape, volume, color, hardness, texture, odor, taste, attraction to magnets.
	MAFS	
	<u>Measurement and Data</u>	
	MAFS.4.MD.1.3	Apply the area and perimeter formulas for rectangles in real world and mathematical problems. For example, find the width of a rectangular room given the area of the flooring and the length, by viewing the area formula as a multiplication equation with an unknown factor.
5	Science	
	<u>Physical Science</u>	
	SC.5.P.10.2	Investigate and explain that energy has the ability to cause motion or create change.

	SC.5.P.13.1	Identify familiar forces that cause objects to move, such as pushes or pulls, including gravity acting on falling objects.
	SC.5.P.13.2	Investigate and describe that the greater the force applied to it, the greater the change in motion of a given object.
	SC.5.P.13.3	Investigate and describe that the more mass an object has, the less effect a given force will have on the object's motion.
	SC.5.P.13.4	Investigate and explain that when a force is applied to an object but it does not move, it is because another opposing force is being applied by something in the environment so that the forces are balanced.
	MAFS	
	MAFS.5.NF.2.6	Solve real world problems involving multiplication of fractions and mixed numbers, e.g., by using visual fraction models or equations to represent the problem.

Design a Telephone		
K	Science	
	<u>Physical Science</u>	
	SC.K.P.10.1	Observe that things that make sound vibrate.
	SC.K.P.8.1	Sort objects by observable properties, such as size, shape, color, temperature (hot or cold), weight (heavy or light) and texture.
I	Science	

	<u>Physical Science</u> SC.1.P.8.1 Sort objects by observable properties, such as size, shape, color, temperature (hot or cold), weight (heavy or light), texture, and whether objects sink or float.
Science	
2	<u>Physical Science</u> SC.2.P.8.1 Observe and measure objects in terms of their properties, including size, shape, color, temperature, weight, texture, sinking or floating in water, and attraction and repulsion of magnets.
Science	
3	<u>Physical Science</u> SC.3.P.10.1 Identify some basic forms of energy such as light, heat, sound, electrical, and mechanical. SC.3.P.10.2 Recognize that energy has the ability to cause motion or create change. SC.3.P.8.3 Compare materials and objects according to properties such as size, shape, color, texture, and hardness.
Science	
4	<u>Physical Science</u> SC.4.P.10.1 Observe and describe some basic forms of energy, including light, heat, sound, electrical, and the energy of motion. SC.4.P.10.2 Investigate and describe that energy has the ability to cause motion or create change.

	<p>SC.4.P.10.3 Investigate and explain that sound is produced by vibrating objects and that pitch depends on how fast or slow the object vibrates.</p> <p>SC.4.P.8.1 Measure and compare objects and materials based on their physical properties including: mass, shape, volume, color, hardness, texture, odor, taste, attraction to magnets.</p>
Science	
5	<u>Physical Science</u>
	SC.5.P.10.1 Investigate and describe some basic forms of energy, including light, heat, sound, electrical, chemical, and mechanical.
	SC.5.P.10.2 Investigate and explain that energy has the ability to cause motion or create change.
	SC.5.P.10.4 Investigate and explain that electrical energy can be transformed into heat, light, and sound energy, as well as the energy of motion.
	SC.5.P.13.2 Investigate and describe that the greater the force applied to it, the greater the change in motion of a given object.
	MAFS
	<u>Numbers and Operations in Base Ten</u>
	MAFS.5.NBT.1.3 Read, write, and compare decimals to thousandths.
	MAFS.5.NBT.2.6 Find whole-number quotients of whole numbers with up to four-digit dividends and two-digit divisors, using strategies based on place value, the properties of operations, and/or the relationship between multiplication and division. Illustrate and explain the calculation by using equations, rectangular arrays, and/or area models.

	MAFS.5.NF.2.3	Interpret a fraction as division of the numerator by the denominator ($a/b = a \div b$). Solve word problems involving division of whole numbers leading to answers in the form of fractions or mixed numbers, e.g., by using visual fraction models or equations to represent the problem.
--	---------------	---

Design a Plant Hydrating System		
K	Science	
	<u>Earth and Space</u>	
	SC.K.E.5.1	Explore the Law of Gravity by investigating how objects are pulled toward the ground unless something holds them up.
	<u>Physical Science</u>	
	SC.K.P.8.1	Sort objects by observable properties, such as size, shape, color, temperature (hot or cold), weight (heavy or light) and texture.
	SC.K.P.9.1	Recognize that the shape of materials such as paper and clay can be changed by cutting, tearing, crumpling, smashing, or rolling.
	MAFS	
	<u>Measurement and Data</u>	
	MAFS.K.MD.1.2	Directly compare two objects with a measurable attribute in common, to see which object has more of/less of the attribute, and describe the difference. For example, directly compare the heights of two children and describe one child as taller/shorter.
I	Science	

	<u>Life Science</u>	
	SC.1.L.14.2	Identify the major parts of plants, including stem, roots, leaves, and flowers.
	SC.1.L.17.1	Through observation, recognize that all plants and animals, including humans, need the basic necessities of air, water, food, and space.
	SC.1.P.8.1	Sort objects by observable properties, such as size, shape, color, temperature (hot or cold), weight (heavy or light), texture, and whether objects sink or float.
	MAFS	
	<u>Measurement and Data</u>	
	MAFS.1.MD.3.4	Organize, represent, and interpret data with up to three categories; ask and answer questions about the total number of data points, how many in each category, and how many more or less are in one category than in another.
2	Science	
	<u>Life Science</u>	
	SC.2.L.17.2	Recognize and explain that living things are found all over Earth, but each is only able to live in habitats that meet its basic needs.
	<u>Physical Science</u>	
	SC.2.P.13.3	Recognize that objects are pulled toward the ground unless something holds them up.
	SC.2.P.13.4	Demonstrate that the greater the force (push or pull) applied to an object, the greater the change in motion of the object.

	SC.2.P.8.1	Observe and measure objects in terms of their properties, including size, shape, color, temperature, weight, texture, sinking or floating in water, and attraction and repulsion of magnets.
	SC.2.P.8.6	Measure and compare the volume of liquids using containers of various shapes and sizes.
	MAFS	
	<u>Measurement and Data</u>	
	MAFS.2.MD.4.10	Draw a picture graph and a bar graph (with single-unit scale) to represent a data set with up to four categories. Solve simple put-together, take-apart, and compare problems using information presented in a bar graph.
3	Science	
	<u>Earth and Space Science</u>	
	SC.3.E.5.4	Explore the Law of Gravity by demonstrating that gravity is a force that can be overcome.
	<u>Life Science</u>	
	SC.3.L.17.2	Recognize that plants use energy from the Sun, air, and water to make their own food.
	<u>Physical Science</u>	
	SC.3.P.8.2	Measure and compare the mass and volume of solids and liquids.
	SC.3.P.8.3	Compare materials and objects according to properties such as size, shape, color, texture, and hardness.

	MAFS	
	<u>Measurement and Data</u>	
	MAFS.3.MD.1.2	Measure and estimate liquid volumes and masses of objects using standard units of grams (g), kilograms (kg), and liters (l). Add, subtract, multiply, or divide to solve one-step word problems involving masses or volumes that are given in the same units.
	MAFS.3.MD.2.3	Draw a scaled picture graph and a scaled bar graph to represent a data set with several categories. Solve one- and two-step how many more and how many less problems using information presented in scaled bar graphs. For example, draw a bar graph in which each square in the bar graph might represent 5 pets.
	MAFS.3.NF.1.1	Understand a fraction $\frac{1}{b}$ as the quantity formed by 1 part when a whole is partitioned into b equal parts; understand a fraction $\frac{a}{b}$ as the quantity formed by a parts of size $\frac{1}{b}$.
4	Science	
	<u>Life Science</u>	
	SC.4.L.16.2	Explain that although characteristics of plants and animals are inherited, some characteristics can be affected by the environment.
	<u>Physical Science</u>	
	SC.4.P.8.1	Measure and compare objects and materials based on their physical properties including: mass, shape, volume, color, hardness, texture, odor, taste, attraction to magnets.
	SC.4.P.8.3	Explore the Law of Conservation of Mass by demonstrating that the mass of a whole object is always the same as the sum of the masses of its parts.
	MAFS	
	<u>Measurement and Data</u>	

	MAFS.4.MD.1.1	Know relative sizes of measurement units within one system of units including km, m, cm; kg, g; lb, oz.; l, ml; hr, min, sec. Within a single system of measurement, express measurements in a larger unit in terms of a smaller unit. Record measurement equivalents in a two-column table. For example, know that 1 ft is 12 times as long as 1 in. Express the length of a 4 ft snake as 48 in. Generate a conversion table for feet and inches listing the number pairs (1, 12), (2, 24), (3, 36), ...
Science		
5	<u>Earth and Space Science</u>	
	SC.5.E.7.1	Create a model to explain the parts of the water cycle. Water can be a gas, a liquid, or a solid and can go back and forth from one state to another.
	SC.5.E.7.5	Recognize that some of the weather-related differences, such as temperature and humidity, are found among different environments, such as swamps, deserts, and mountains.
	<u>Life Science</u>	
	SC.5.L.14.2	Compare and contrast the function of organs and other physical structures of plants and animals, including humans, for example: some animals have skeletons for support -- some with internal skeletons others with exoskeletons -- while some plants have stems for support.
	SC.5.L.15.1	Describe how, when the environment changes, differences between individuals allow some plants and animals to survive and reproduce while others die or move to new locations.
	SC.5.L.17.1	Compare and contrast adaptations displayed by animals and plants that enable them to survive in different environments such as life cycles variations, animal behaviors and physical characteristics.
MAFS		
	<u>Numbers and Operations in Base Ten</u>	

	MAFS.5.NBT.2.5	Fluently multiply multi-digit whole numbers using the standard algorithm.
	<u>Measurement and Data</u>	
	MAFS.5.MD.2.2	Make a line plot to display a data set of measurements in fractions of a unit ($\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$). Use operations on fractions for this grade to solve problems involving information presented in line plots.
	MAFS.5.MD.3.4	Measure volumes by counting unit cubes, using cubic cm, cubic in, cubic ft, and improvised units.
	<u>Operations and Algebraic Thinking</u>	
	MAFS.5.OA.1.2	Write simple expressions that record calculations with numbers, and interpret numerical expressions without evaluating them.

Board Game Challenge		
	MAFS	
	<u>Counting and Cardinality</u>	
	MAFS.K.CC.2.4	Understand the relationship between numbers and quantities; connect counting to cardinality.
	<u>Geometry</u>	
	MAFS.K.G.1.3	Identify shapes as two-dimensional (lying in a plane, flat) or three-dimensional (solid).
K	MAFS.K.G.2.5	Model shapes in the world by building shapes from components (e.g., sticks and clay balls) and drawing shapes.
	MAFS.K.G.2.6	Compose simple shapes to form larger shapes.
	<u>Measurement and Data</u>	

	MAFS.K.MD.1.1	Describe measurable attributes of objects, such as length or weight. Describe several measurable attributes of a single object.
	MAFS.K.MD.1.2	Directly compare two objects with a measurable attribute in common, to see which object has more of/less of the attribute, and describe the difference. For example, directly compare the heights of two children and describe one child as taller/shorter.
	<u>Operations and Algebraic Thinking</u>	
	MAFS.K.OA.1.1	Represent addition and subtraction with objects, fingers, mental images, drawings, sounds (e.g., claps), acting out situations, verbal explanations, expressions, or equations.
	MAFS.K.OA.1.a	Use addition and subtraction within 10 to solve word problems involving both addends unknown, e.g., by using objects, drawings, and equations with symbols for the unknown numbers to represent the problem. (Students are not required to independently read the word problems.)
	MAFS.K.OA.1.2	Solve addition and subtraction word problems, and add and subtract within 10, e.g., by using objects or drawings to represent the problem (Students are not required to independently read the word problems.)
	MAFS.K.OA.1.5	Fluently add and subtract within 5.
I	MAFS	
	<u>Geometry</u>	
	MAFS.1.G.1.2	Compose two-dimensional shapes (rectangles, squares, trapezoids, triangles, half-circles, and quarter-circles) or three-dimensional shapes (cubes, right rectangular prisms, right circular cones, and right circular cylinders) to create a composite shape, and compose new shapes from the composite shape.
	<u>Measurement and Data</u>	

	<p>MAFS.1.MD.1.a Understand how to use a ruler to measure length to the nearest inch.</p> <p><u>Operations and Algebraic Thinking</u></p> <p>MAFS.1.OA.1.2 Solve word problems that call for addition of three whole numbers whose sum is less than or equal to 20, e.g., by using objects, drawings, and equations with a symbol for the unknown number to represent the problem.</p> <p>MAFS.1.OA.3.5 Relate counting to addition and subtraction (e.g., by counting on 2 to add 2).</p>
	MAFS
2	<p><u>Measurement and Data</u></p> <p>MAFS.2.MD.1.1 Measure the length of an object to the nearest inch, foot, centimeter, or meter by selecting and using appropriate tools such as rulers, yardsticks, meter sticks, and measuring tapes.</p> <p>MAFS.2.MD.2.5 Use addition and subtraction within 100 to solve word problems involving lengths that are given in the same units, e.g., by using drawings (such as drawings of rulers) and equations with a symbol for the unknown number to represent the problem.</p> <p><u>Operations and Algebraic Thinking</u></p> <p>MAFS.2.OA.1.1 Use addition and subtraction within 100 to solve one- and two-step word problems involving situations of adding to, taking from, putting together, taking apart, and comparing, with unknowns in all positions, e.g., by using drawings and equations with a symbol for the unknown number to represent the problem.</p> <p><u>Geometry</u></p> <p>MAFS.2.G.1.1 Recognize and draw shapes having specified attributes, such as a given number of angles or a given number of equal faces. Identify triangles, quadrilaterals, pentagons, hexagons, and cubes.</p>

MAFS	
3	<u>Measurement and Data</u> MAFS.3.MD.2.4 Generate measurement data by measuring lengths using rulers marked with halves and fourths of an inch. Show the data by making a line plot, where the horizontal scale is marked off in appropriate units—whole numbers, halves, or quarters.
	<u>Numbers and Operations in Base Ten</u> MAFS.3.NBT.1.2 Fluently add and subtract within 1000 using strategies and algorithms based on place value, properties of operations, and/or the relationship between addition and subtraction.
	MAFS.3.NBT.1.3 Multiply one-digit whole numbers by multiples of 10 in the range 10–90 (e.g., 9×80 , 5×60) using strategies based on place value and properties of operations.
	<u>Operations and Algebraic Thinking</u> MAFS.3.OA.1.3 Use multiplication and division within 100 to solve word problems in situations involving equal groups, arrays, and measurement quantities, e.g., by using drawings and equations with a symbol for the unknown number to represent the problem.
	<u>Geometry</u> MAFS.3.G.1.1 Understand that shapes in different categories (e.g., rhombuses, rectangles, and others) may share attributes (e.g., having four sides), and that the shared attributes can define a larger category (e.g., quadrilaterals). Recognize rhombuses, rectangles, and squares as examples of quadrilaterals, and draw examples of quadrilaterals that do not belong to any of these subcategories.
MAFS	
	<u>Geometry</u>

4	MAFS.4.G.1.1	Draw points, lines, line segments, rays, angles (right, acute, obtuse), and perpendicular and parallel lines. Identify these in two-dimensional figures.
	<u>Measurement and Data</u>	
	MAFS.4.MD.1.1	Know relative sizes of measurement units within one system of units including km, m, cm; kg, g; lb, oz.; l, ml; hr, min, sec. Within a single system of measurement, express measurements in a larger unit in terms of a smaller unit. Record measurement equivalents in a two-column table.
	<u>Numbers and Operations in Base Ten</u>	
	MAFS.4.NBT.2.4	Fluently add and subtract multi-digit whole numbers using the standard algorithm.
	<u>Operations and Algebraic Thinking</u>	
5	MAFS.4.OA.1.2	Multiply or divide to solve word problems involving multiplicative comparison, e.g., by using drawings and equations with a symbol for the unknown number to represent the problem, distinguishing multiplicative comparison from additive comparison.
	MAFS.4.OA.3.5	Generate a number or shape pattern that follows a given rule. Identify apparent features of the pattern that were not explicit in the rule itself.
	MAFS	
5	<u>Numbers and Operations in Base Ten</u>	
	MAFS.5.NBT.2.5	Fluently multiply multi-digit whole numbers using the standard algorithm.

	<p>MAFS.5.NBT.2.7 Add, subtract, multiply, and divide decimals to hundredths, using concrete models or drawings and strategies based on place value, properties of operations, and/or the relationship between addition and subtraction; relate the strategy to a written method and explain the reasoning used.</p>
--	---