



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

Pre-Activity Curriculum Guide

Level: Basic

Curtis Rising Stars 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 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 Orlando Science Center where students will put their skills into practice via a competition.

Objective

This competition challenges young elementary student teams of 2 – 4 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 Orlando Science Center.

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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 Stars 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. 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

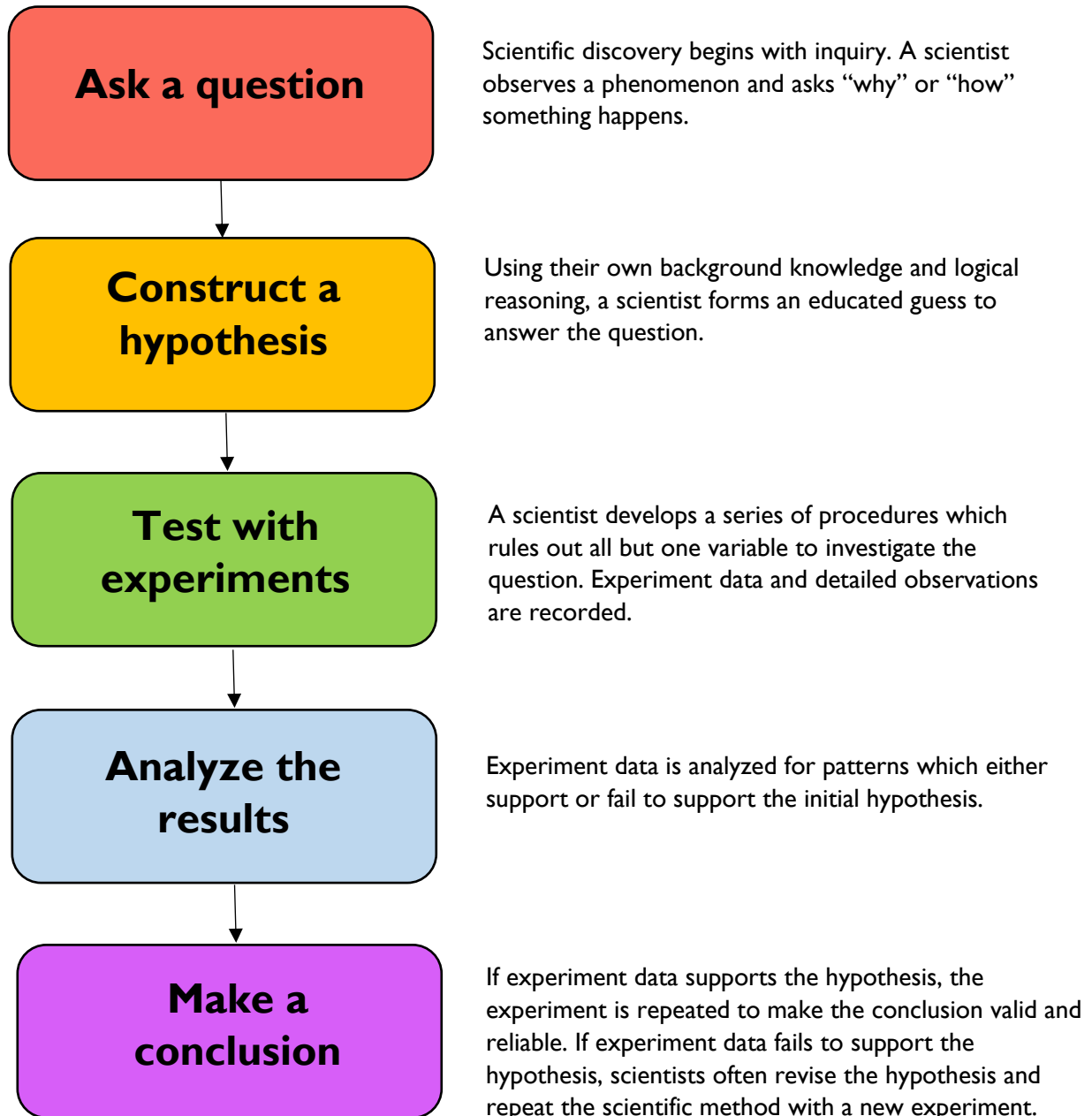
STEM education is an interdisciplinary approach to learning, combining multiple academic subjects, focusing on the real-world impact of these lessons. It is about students applying science, technology, engineering and mathematics in contexts that make relevant connections between themselves and their school, community, 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 own 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.

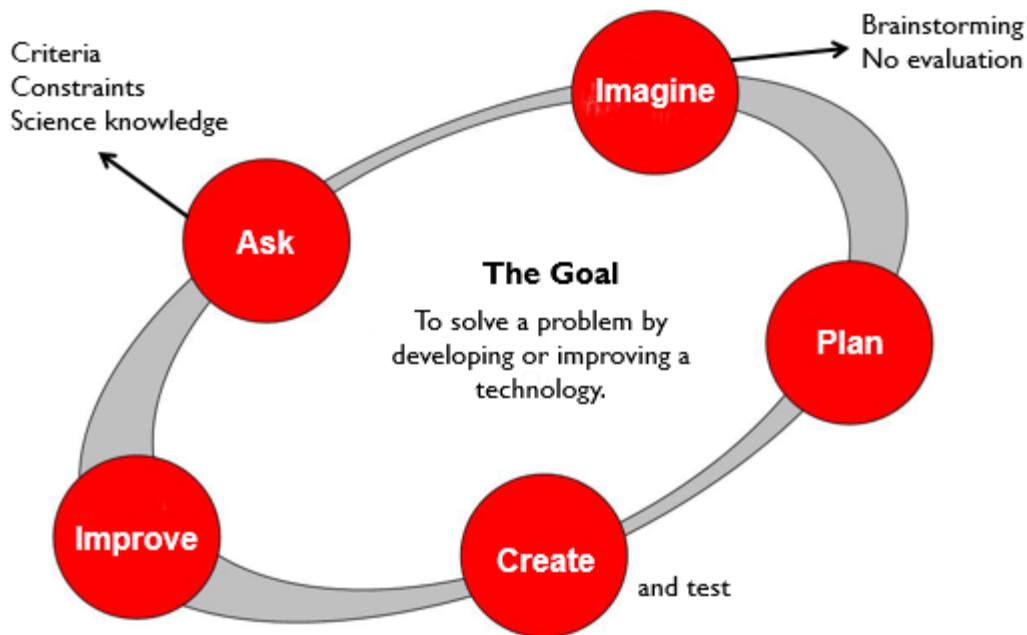


Scientific Method Activity Resources:

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/gen-science/SSubramaniam09.html>
“Testing the Scientific Method Through Thumb Wars”
Grade Level: 3 – 5
Students will have an opportunity to go through the entire process of the scientific method using the game "Thumb Wars".
*Note: this activity is written for grades 6-8 but can easily be modified for upper-elementary students.
- Source: Ben Finio, Science Buddies
<https://www.sciencebuddies.org/teacher-resources/lesson-plans/teach-scientific-method?from=Blog>
“Teaching the Scientific Method with Paper Rockets”
Grade Level: 3-5
In this activity, students work through the scientific method as they create and test paper rockets.

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 (EDP) 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 evidence is gathered that either supports or does not support it. 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 they create one possible solution to this problem and considers math and science 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 EDP 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 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 Stars Science Challenge, student success will be measured using the following criteria:

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

Students will be assessed at 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 page contains the rubric with specific criteria which will be used when judging student designs at the Curtis Rising Stars Science Challenge. Educators should use this rubric when evaluating student success in the pre-activities to familiarize themselves with it and to prepare students for what will be expected from them at the event.

Team: _____

Curtis Rising Stars Student Success Rubric

Total Score: _____

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 to re-design using information gathered from testing.	✓ No attempt to solve the problem ✓ No attempts to re-design	✓ Attempts to solve the problem ✓ Attempts to re-design	✓ 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.	✓ No attempt to explain ideas ✓ Not listening ✓ No attempt at one group design	✓ Attempts to explain ideas ✓ Listens, but often argues or interrupts each other ✓ Attempts group design, no clear decision made	✓ 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 asked of them.	✓ No explanation behind design choices ✓ No justification whether a design has or has not met the design criteria.	✓ Unclear or incomplete explanations of design choices ✓ Partially justifies whether a design has or has not met the design criteria	✓ Clear and complete explanations of design choices ✓ Justifies whether a design has or has not met the design criteria
Creativity The student team displays original ideas or ways to improve existing ideas.	✓ No original ideas or ways to improve existing ideas	✓ One original idea or way to improve an existing idea	✓ Three or more original ideas or ways to improve an existing idea
Content Understanding The student team conveys understanding of math and science concepts related to the challenge.	✓ Conveyed no understanding of relevant math and science concepts	✓ Conveyed <i>minimal</i> understanding of some relevant math and science concepts	✓ Conveyed <i>complete</i> understanding of all relevant math and science concepts
Content Application The student team applies relevant math and science concepts to their design and improvements.	✓ No application of relevant math and science concepts to their design and improvements	✓ <i>Minimal</i> application of relevant math and science concepts to their design and improvements	✓ Application of relevant science and math concepts to their design and improvements

Design a Scaffolding System

Prep: 5 – 10 minutes

Activity: 65 minutes

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

Background

A **force** is a push or 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 forces of attraction between objects which 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 resource:

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

Pre-Requisite Knowledge

Students should have comprehension of the following concepts, appropriate to their grade level:

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)
- Soft-cover book or journal, approximately 7 ½" x 10"
- 8 oz. plastic cup
- Approximately 100 small objects of the same mass (i.e. hex nuts, gram units, marbles)
- Examples of Scaffolding Systems

For Each Pair of 2 Students

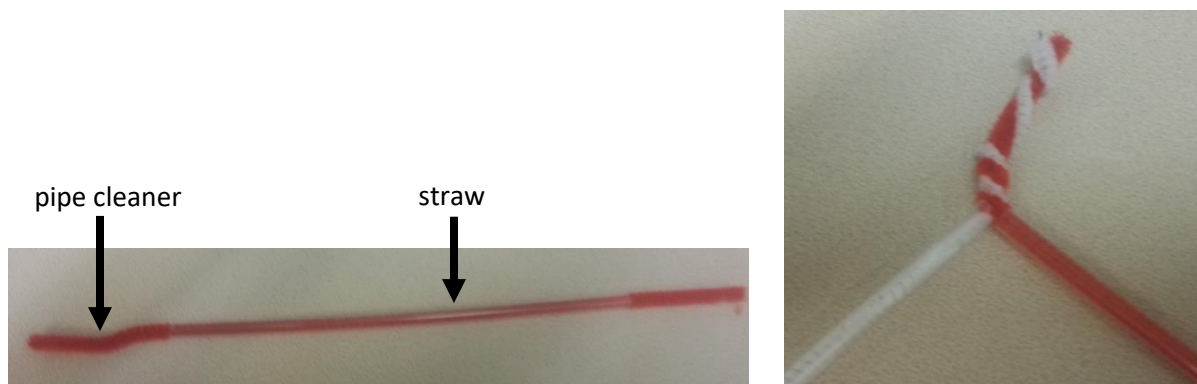
- 23 plastic drinking straws, non-bendy
- 23 pipe cleaners (must fit inside of the drinking straws and be at least 2 inches longer than the straws)
- ruler marked in inches

For Each Student

- Pencil
- Pages 3-6 of the Basic Engineering Notebook (or blank paper)

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.



Introduction (15 minutes)

1. Review with students what they have learned about force and motion. Ask:
 - **What is a force?** *(A force is a push or pull that may change the motion of an object.)*
 - **What is the force that pulls objects toward the surface of the earth?** *(gravity)*
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. Show students images of buildings and other human-made structures in real life.
 - If students have trouble thinking of how these structures stand up to gravity, do a short demonstration with an index card. As a class, brainstorm how to make the card stand without holding it up. Lead the students to discover that we can change the shape from two-dimensional (flat) to three-dimensional (solid) by folding, taping to another card to form a corner, etc.
4. 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.
5. 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.)*
6. 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 which 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.
 - For younger students, simplify the goal: **Design a scaffolding system which is tall enough to reach the top floor of the building and stable enough to balance on its own.**
 - Also, substitute the word “weight” for “mass” if grade-appropriate.
7. 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.)*
- If students are having trouble coming up with questions, try saying, “Ok then go ahead and get started.” The students will probably be confused and say, “We don’t have anything to build with.” Then you can add the question “What materials will we have?” Students may need similar prompting to think of other questions.
8. Record students’ questions on the board. Guide students to ask the following questions:
- **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 long does the scaffolding system need to stand for?**
 - **How long will we have to create our designs?**
 - **What materials can we use?**
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.
- **Height:** 6 inches- students will measure to the nearest whole inch.
 - Alternatively, students may measure the height of their structures with non-standard units of measurement that they are currently using in math.
 - **Mass: the mass of the workers is the mass of the book or journal.** This is the minimum mass the scaffolding system must be able to support.
 - Pass around the book/journal for students to feel the weight. Share the actual mass in grams of the book/journal and one of the “building materials” with the 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.
- **Time:** (show the students each corresponding page in their notebooks)
 - Each student will have 5 minutes to imagine ideas in their notebooks.
 - Teams will then collaborate for 5 minutes to develop a plan.
 - Once the plan has been approved by the teacher, teams will have 15 minutes 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 minutes to improve their designs.
 - We will test the height, strength, and stability of our improved designs.
- **Materials:** Show the students how to use their 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 20 plastic drinking straws (which represent the support beams) and 20 pipe cleaners (which represent the connector joints).
 - Show students how to create a support column and connecting joint.
 - If students have the fine motor skills to use scissors, they may also be given scissors to change the length of the straws and pipe cleaners.

Activity (45 minutes)

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: 3 straws and 3 pipe cleaners. 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.

3. Give students 5 minutes 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 minutes, 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 person's. Tell the groups to draw their ideas in their notebooks.
5. Give students 5 minutes to collaborate and form a plan. Circulate during this time, asking students questions:
 - What do you think about _____'s idea?
 - Has everyone had 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 minutes, 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*)
8. Tell students that they will have 15 minutes 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.
9. Give each group their building materials and set a timer for 15 minutes. 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?

10. After 15 minutes, 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 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.

Teacher Tip:

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

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 minutes 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.

12. Set a timer for 10 minutes. 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 minutes, test each group's design one at a time while the rest of the class watches. For each group:

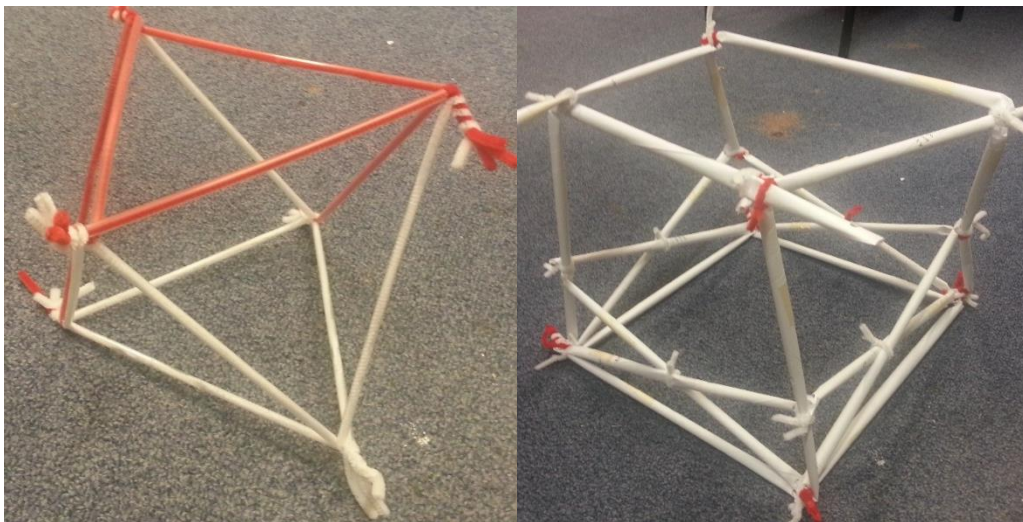
- Have the group share their idea with the rest of the class and briefly explain how they improved the design. Measure the height to make sure it meets the minimum requirement.
- Make sure the design can balance on its own. If it can, that group can check off "stability" in their notebooks.
- Lay the book representing the workers' mass on top of the design. Count to 30. If the design fails before 30 seconds, the group will record the time in their notebooks.

14. 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 minutes)

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 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>

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Design a Roller Coaster

Prep: 5 – 10 minutes

Activity: 65 minutes

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 converts 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 which 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 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/>
- <https://www.ducksters.com/science/physics/>

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Pre-Requisite Knowledge

Students should have comprehension of the following concepts, appropriate to their grade level:

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 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:** "Forms of Energy"
 - This lesson helps students explore the different forms of energy, including mechanical, electrical, chemical, heat, light, and sound.
 - <https://www.cpalms.org/PreviewResourceStudentTutorial/Preview/215786>

Materials

For the Class:

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

For Each Group of Students

- 1 Timer
- 1 Glass marble
- Chair
- 22 sheets of paper, 8 1/2" x 11" - **tip- use recycled paper**
- Scissors
- Examples of how to change paper's shape

For Each Student

- Pencil
- Pages 7-10 of the Basic Engineering Notebook (or blank paper)

Introduction (15 minutes)

1. Review what students learned in the scaffolding system activity about force and motion.
 - Connect the discussion about energy to what students have learned about sound vibrations.
 - Do not discuss potential and kinetic energy or friction if it is not grade-appropriate.
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 which converts energy to heat when objects rub together. This means that objects have less kinetic energy and slow down.*
5. Review with students what engineering is. Ask:
 - **What is an engineer?** *(An engineer is a person who uses their creativity and knowledge of science and math to design and improve technology to solve problems.)*
 - **What is the process that engineers follow 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.)*
6. Explain to the students that they are going to be engineers using the engineering design process to solve a problem.
 - **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 which goes from a chair to the floor. The roller coaster must be safe.
7. 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.)*
8. Record students' questions on the board. Guide students to the following questions:
 - **What is 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?**
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.

- **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.
- **Time:** (show the students each corresponding page in their notebooks)
 - Each student will have 5 minutes to imagine ideas in their notebooks.
 - Teams will then collaborate for 5 minutes to develop a plan.
 - Once the plan has been approved by the teacher, teams will have 15 minutes 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 minutes to improve their designs.
 - We will test the fun and safety of our improved designs.
- **Materials:**
 - Students will receive 1 foot 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 and scissors. A marble will represent the roller coaster car. The tracks can be taped to furniture for support.
- **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 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?**

Teacher Tip:

Shorten the length of this activity as is suited to the students' attention spans. It may be more efficient for younger students to make improvements as they build rather than stopping for formal tests. Students should still be asked questions about how they improved so they still reflect and focus on the process.

- 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.
- Students are not required to have turns or hills. Instead, have a discussion about how to shape the paper to keep the ball on the track. If necessary, model how the marble will roll off a piece of paper with no sides, and ask how we can make it stay on the track. Students may discuss railings, tubes, etc.

10. 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 minutes)

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: 2 sheets of paper, 6 inches of masking tape, and scissors. 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.
3. Give students 5 minutes 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 minutes, 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 person’s. Tell the groups to draw their ideas in their notebooks.

5. Give students 5 minutes to collaborate and form a plan. Circulate during this time, asking students questions:
 - What do you think about _____'s idea?
 - Has everyone had 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 minutes, 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 minutes 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 minutes. 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 minutes, 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.
 - 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

Teacher Tip:

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

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.

them an extra challenge (i.e. make the track longer, put in a turn).

10. Ask students which step is next in the engineering design process. (*improve*) Tell students that they will have 10 minutes 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.
11. Set a timer for 10 minutes. 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 minutes, 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.

Reflection (5 minutes)

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>





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Design Play Dough

Prep: 5 – 10 minutes

Activity: 65 minutes

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 peers(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 these 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 which 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 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, 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:

- Kids Discover
"Unit: Matter"
<https://online.kidsdiscover.com/unit/matter>
- Generation Genius
"Properties of Matter"
<https://www.generationgenius.com/videolessons/properties-of-matter-video-for-kids/>

Pre-Requisite Knowledge

Students should have comprehension of the following concepts, appropriate to their grade level:

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 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 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 white board
- Sink with running water
- Optional: food coloring, glitter
- 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 tablespoon measuring spoon
- Two wooden craft sticks
- One plastic spoon
- 3 cups, 8 oz.
- Plastic or Styrofoam bowl (can use paper, but it will get soggy)
- Recipe step cards
- Scissors
- Glue or tape

For Each Student

- Pencil
- Pages 11-16 of the Basic Engineering Notebook (or blank paper)

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 seconds
 - Add $\frac{1}{4}$ cup of salt and stir for 30 seconds or until the mixture is too thick to stir.
 - Remove the mixture from the bowl and knead with hands for 30 seconds 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, use the following steps to 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 minute. If needed, continue stirring until the salt is completely dissolved. Mix in 3 drops of food coloring and stir for 30 seconds, or until evenly mixed.
 - In a separate large mixing bowl, mix 2 cups of flour and 2 tablespoons of cream of tartar. Stir for 10 seconds.
 - Add the salt/water mixture and 2 tablespoons of vegetable oil to the flour/tartar mixture. Stir for 30 seconds, or until the mixture is too thick to stir.
 - Remove the mixture from the bowl and knead on a flat surface for 30 seconds. or until it reaches a play dough consistency.
 - Humidity levels will affect the consistency of the play dough. If it becomes too sticky, gradually add small amounts of flour until a play dough consistency is achieved. If it is too dry, gradually add small amounts of water.

Introduction (15 minutes)

1. Review what students learned in class about matter (only discuss solids and liquids) 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 with students what engineering is. Ask:
 - **What is an engineer?** *(An engineer is a person who uses their creativity and knowledge of science and math to design and improve technology to solve problems.)*
 - **What is the process that engineers follow 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.)*
4. Explain to the students that they are going to be engineers using the engineering design process to solve a problem.
 - **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.
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. Guide students towards the following questions:
 - **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?**

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.

- **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
 - a. If you are not providing color as an option, do not record observations about color in the chart. Inform students that the play dough will only be scored based on how it feels and if it can be shaped easily and maintain its shape.
- 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.
- Instruct students to complete the Play Dough Quality chart in their notebooks.

- **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.
 - If it will be too overwhelming for your students to determine the amount and the order, see alternative “plan” procedures. The class will determine the order together, and groups will only decide on the amount of each ingredient.
- **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 receive 1 cup of each: Flour, salt, and water. Groups will decide how much of each ingredient to add and the order to add them in.
 - Optional: Allow students to add food coloring and/or glitter to their play dough if they want to.
- **How much time will we have?**
 - Each student will have 5 minutes to imagine ideas as a group.
 - Teams will then collaborate for 5 minutes to develop a plan.
 - Once the plan has been approved by the teacher, teams can begin creating play dough. Students can test and improve as they go during the 25 minute create time. However, each time they finish making a batch they must score, evaluate, and then begin a new, improved batch.
 - After 25 minutes we will share our final play dough and explain the improvements we made throughout.

Teacher Tip:

Shorten the length of this activity as is suited to the students’ attention spans. It may be more efficient for younger students to make improvements as they build rather than stopping for formal tests. Students should still be asked questions about how they improved so they still reflect and focus on the process.

Activity (45 minutes)

- I. 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 and ingredients. 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. Students should record these observations.
 - Ask students to look at the scoring rubric and discuss with their groups which ingredient they think contributes each property to the play dough. Students should record their thoughts in their notebooks.
 - After a few minutes, 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 minutes, 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 person’s. Tell the groups to draw their ideas in their notebooks.
4. Give students 5 minutes 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 ingredients from the “imagine” portion. Circulate during this time, asking students questions:
 - What do you think about _____’s idea?
 - Has everyone had 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 minutes, 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 minutes 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.

Teacher Tip:

If students are determining the order as a class, lead students through mixing two materials at a time to discover the changes this creates in properties. Students should be led to realize that if the salt is not added to water before flour, the salt does not dissolve. Dissolving salt in water therefore should be the first step, and then flour is added.

8. Give each group their building materials and set a timer for 25 minutes. Each group receives a cup of each: Flour, salt, and water. They should measure out tablespoons from these and mix them in their bowls. Remind students to clean off their tablespoons between ingredients. 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 minutes, 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 minutes)

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 can then improve their recipes based on feedback from the other group.

Water Runoff Reduction System

Prep: 5 – 10 minutes

Activity: 65 minutes

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

Background

All life on Earth requires water 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 really 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 liquid form, such as rivers, lakes, and oceans. Water also exists on the Earth's surface in solid forms as snow and ice. As the snow and ice is heated, some of it 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 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 away rock 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: <https://www.nps.gov/articles/000/weathering-erosion.htm>

Pre-Requisite Knowledge

Students should have comprehension of the following concepts, appropriate to their grade level:

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 precipitation, such 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.
- Can compare numbers using the terms 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 centimeters.

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: <https://www.cpalms.org/PreviewResourceStudentTutorial/Preview/163735>

Materials

For the Class:

- 6 oz. paper or plastic cup
- Sink with running water
- 1 roll of aluminum foil
- Blue food coloring
- 1 tbsp. of each: glitter, vegetable oil, confetti
- Duct tape
- 1 model urban landscape (see prep)
- Engineering Design Process (on the board or on chart paper)

Teacher Tip:

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

For Each Group of Students

- Rectangular container (i.e. aluminum baking pan), at least 9" x 9", between 2" – 4" tall
- sand (enough to fill half the rectangular container)
- 2-3 small objects (i.e. wooden block, cup)
- Paper/plastic cup, 6 oz.
- Sponge, approximately 3" x 5"
- 10 Rocks (approximately ½ - 1 in. diameter)
- Aluminum foil, approximately 12" x 12"
- Craft felt, approximately 12" x 12"
- Play dough, approximately ¼ cup (use play dough recipe from previous activity)
- Scissors

For Each Student

- Pencil
- Pages 17-21 of the Basic engineering notebook (or blank paper)

Prep

- Create a model landscape for each group in a rectangular container at least 9" x 9" and 2 – 4" tall. All the containers must be the same size. Larger containers will be easier to use.
 - Fill half of the container with approximately 1 ½ inches of 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 ½ inch between the foil and the top of the container.

- Cover 2-3 small objects 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 approximately 1 inch deep. Make sure all containers have 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.

Sample Model Landscape



Water
level
marked
in cm

Introduction

1. Discuss weather students have observed, and how rainwater moves once it has reached the Earth's surface. Relate this to gravity.
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 the pollution or eating animals who are sick from the pollution.)*
4. Review with students what engineering is. Ask:
 - **What is an engineer?** *(An engineer is a person who uses their creativity and knowledge of science and math to design and improve technology to solve problems.)*
 - **What is the process that engineers follow 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 using the engineering design process to solve a problem.
 - **Problem:** A city's pollution is spreading to a nearby river because of water runoff! They need to reduce water runoff to prevent the spread of pollution.
 - **Goal:** Create a system which will reduce water runoff in an urban landscape.
 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. Guide students towards the following questions:
 - **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?**
 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.
 - **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 objects wrapped in foil represent buildings made of concrete, metal, and glass.
 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 the areas, for about 15 seconds.
 - 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.
- Each group will receive a set of materials which they can use to create their runoff reduction system. Groups do not have to use all the materials, but they will not receive any additional materials. Each group will receive: 1 sponge (3" x 5"), 10 rocks, a sheet of aluminum foil (12" x 12"), and a sheet of craft felt (12" x 12"). Students will also receive ¼ cup of play dough, which they can use to create structures or to stick the other materials to the model city.

Teacher Tip:

Play dough has been substituted instead of duct tape because it is easier to manipulate. If your students have the necessary motor skills, give them tape instead.

Teacher Tip:

Shorten the length of this activity as is suited to the students' attention spans. It may be more efficient for younger students to make improvements as they build rather than stopping for formal tests. Students should still be asked questions about how they improved so they still reflect and focus on the process.

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

- Each student will have 5 minutes to imagine ideas in their notebooks.
- Teams will then collaborate for 5 minutes to develop a plan.
- Once the plan has been approved by the teacher, teams will have 15 minutes 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 minutes 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 this goal and the original water level of the lake in their notebook.

Teacher Tip:

Use whole cm to measure the height of the model lake. Round up or down to the nearest whole cm as appropriate.

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: a Ziploc bag containing a tbsp. of sand (tape shut so students do not open), sponge (approximately 1" x 1"), 1 rock (approximately 1/2 - 1 in. diameter), aluminum foil (approximately 1" x 1"), craft felt (approximately 1" x 1"), and a small amount of play dough. 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 minutes 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?
4. After 5 minutes, 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 person's. Tell the groups to draw their ideas in their notebooks.
 5. Give students 5 minutes to collaborate and form a plan. Circulate during this time, asking students questions:
 - What do you think about _____'s idea?
 - Has everyone had 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 minutes, 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 minutes 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 minutes 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 minutes, 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 minutes 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.
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 minutes. 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 minutes, 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 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 minutes

Activity: 65 minutes

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 peers 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 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 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.

Resources

See resources in the front of this guide about the scientific method and the engineering design process.

Pre-Requisite Knowledge

Students should have comprehension of the following concepts, appropriate to their grade level:

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 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
- How to measure with a ruler (or with non-standard units of measurements, whichever is the grade level's standard)
- How to keep written and/or pictorial records of observations
- Differentiating between opinions and facts
- Justifying explanations verbally and/or on paper with scientific observations

Advanced

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

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.)
- 50 sheets of 8 1/2" x 11" copy paper
- 50 index cards, 3" x 5"
- 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

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

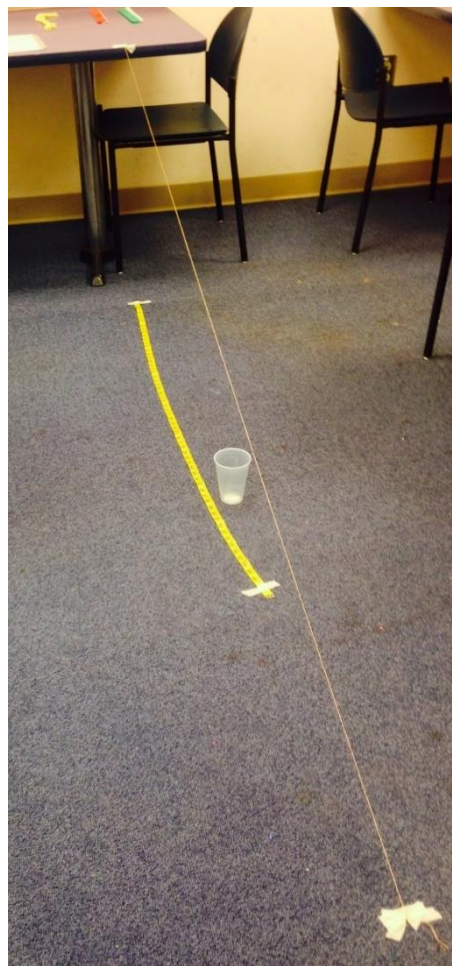
For Each Student

- Pages 22-25 of the Basic Engineering Notebook (or blank paper)
- 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 taut.
- 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 the differences between the scientific method and engineering design process with students:
 - **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.**
3. 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 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?**
4. 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 which 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.
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. Guide students towards the following questions:
 - **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?**
 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.
 - **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 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 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 feet.
 - 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 tape to 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.**
- **Materials**
 - Show the students the materials they may choose from. 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.
- **Time**
 - Each student will have 5 minutes to imagine ideas in their notebooks.
 - Teams will then collaborate for 5 minutes to develop a plan.
 - Once the plan has been approved by the teacher, teams will have 15 minutes 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 minutes to improve their designs.
 - We will test the height, strength, and stability of our improved designs.

Teacher Tip:

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

Teacher Tip:

Shorten the length of this activity as is suited to the students' attention spans. It may be more efficient for younger students to make improvements as they build until it successfully balances on its own, rather than stopping for formal tests. Students should still be asked questions about how they improved so they still reflect and focus on the process.

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 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.
3. Give students 5 minutes 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."
4. After 5 minutes, 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 person's. Tell the groups to draw their ideas in their notebooks.
 5. Give students 5 minutes to collaborate and form a plan. Circulate during this time, asking students questions:
 - What do you think about _____'s idea?
 - Has everyone had 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 minutes, 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 minutes 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.
 8. Have each group retrieve 5 materials from the materials table and set a timer for 15 minutes. 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 minutes, 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.
 - Have students check off whether or not the payload lands in the cup.
10. Ask students which step is next in the engineering design process. (*improve*) Tell students that they will have 10 minutes 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.
11. Set a timer for 10 minutes. 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 minutes, 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.
 - 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 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>

Example Images of Zip Lines



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 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 minutes

Activity: 65 minutes

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 peers to design a model paper helicopter 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 design with their classmates and compare different designs to appreciate the creativity that goes into engineering.

Background

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

Drag is a force which 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 which 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 on 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 comprehension of the following concepts, appropriate to their grade level:

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 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. 13)
- Design a Roller Coaster (p. 26)

Materials

For the Class:

- Engineering Design Process (on the board or on chart paper)
- "Paper Copter Shape Test: Circle"-print on copy paper (page 83)

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- “Paper Copter Shape Test: Square”- print on copy paper (page 84)
- “Paper Copter Shape Test: Triangle”- print on copy paper (page 85)
- 3 small paper clips (same mass)
- “Blade Shape Templates”- print on cardstock (page 86-89)

For Each Pair of Students

- 3 sheets of copy paper
- Paper copter template
- Scissors
- 2 ft. of Scotch tape
- Optional: Crayons/markers to decorate paper-copters

For Each Student

- Pencil
- Pages 26-31 of the Basic Engineering Notebook (or blank paper)

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 on the top bottom line.
 - 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.
- Print the “Blade Shapes Template” on cardstock and cut each shape out. **Note: It is not necessary to print on cardstock, but will reduce the damage cause by repeated tracing.** Label each size of each shape 1-5, 1 on smallest and 5 on largest. When students plan, they will write the size they choose.
- Print one “Paper Copter Test: Size” template per group. Groups can choose the template they want for their base copter.

Introduction (15 minutes)

1. Review with students what they have learned about force and motion. Ask:
 - **What is a force?** *(A force is a push or pull that may change the motion of an object.)*
 - **What is the force that pulls objects toward the surface of the earth?** *(gravity)*
 - **What is friction, and how does it affect the motion of an object?** *(Friction is a force which 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/backwards)*
4. Ask students to open their notebooks. 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. *For younger students, demonstrate drag by dropping a flat sheet of paper. Lead students in observing how the paper drifts down to the ground and flutters as it moves against the air.*
5. Review with students what engineering is. Ask:
- **What is an engineer?** *(An engineer is a person who uses their creativity and knowledge of science and math to design and improve technology to solve problems.)*
 - **What is the process that engineers follow 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.)*
6. Explain to the students that they are going to be engineers using the engineering design process to solve a problem. 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.

7. 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.)*
8. Record students’ questions on the board. Guide students to ask the following questions:
 - **What is a “paper-copter,” and how is it similar/different to a helicopter?**
 - **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?**

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.

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).

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 minutes to imagine ideas in their notebooks.
- Teams will then collaborate for 5 minutes to develop a plan.
- Once the plan has been approved by the teacher, teams will have 15 minutes 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 minutes to make improvements to their design.

Materials:

- Students will receive a paper-copter body. Students will choose which shape and size to add to their paper-copter's blades. Show students the templates they will trace onto copy paper and cut out. Explain that students will have tape to use to attach shapes. Students can also make any modifications they choose to the body. Students will receive 2 sheets of copy paper and 1 foot of tape to make modifications to their paper-copter body. Students will receive 1 additional sheet of paper and 1 additional foot of tape during the improve stage.

Teacher Tip:

Shorten the length of this activity as is suited to the students' attention spans. It may be more efficient for younger students to make improvements as they build rather than stopping for formal tests. Students should still be asked questions about how they improved so they still reflect and focus on the process. Have a "show-case" for each group at the end to share their design with the other groups.

Teacher Tip

If students have the fine motor skills, allow them to draw and cut out their own shapes for the blades. They need to be able to measure the length and width of the blades using cm or inches.

How will we measure our design's success?

- 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 minutes)

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 shape test paper-copters: Square, circle, and triangle. Explain that during the imagine portion, students will observe a paper-copter with each blade shape dropping from the same height. Show students where they will record drop times for each shape 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 students to identify each blade shape as a circle, square, and triangle.
4. Measure the length and width of each shape (or have a student measure it and share measurements with the class). Each shape has the *same* length and width: 3 inches. Clarify: **The blades have the same length and width, but they are different shapes.**
5. Ask students to predict **which shape will fall the most slowly and which will fall the fastest**. Have students explain the reasoning behind their predictions.
6. Drop each shape test paper-copter from the same height one at a time. The adult should drop the copters while students observe and record drop times.
 - Hold the paper-copter so the blades are on top. Hold just underneath the blades with your forefinger and thumb.
 - Position the *bottom* of the paper-copter base level with the drop height.
 - Count down and release the paper-copter on “go!” Count how many seconds it takes for the paper-copter to hit the ground.
 - Have students record the drop time for each copter in their notebooks.
7. Create a bar graph on the board with students. Have volunteer students draw a bar for each shape test copter to the number of seconds it took to drop.
8. Guide students to evaluate the results:
 - Order the blade shapes from *greatest* drop time (slowest) to *least* drop time (fastest). Record in notebooks. (*The order should be: Square, circle, triangle. If it is not, there was an*

Teacher Tip:

For the imagine tests, it is recommended that the teacher drop all 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.

error in the testing; this is why it is recommended to test the copters ahead of time so you get reliable results)

- **Which blade shape was the most successful?** (Square)
 - **Which blade shape was the least successful?** (Triangle)
 - Ask students to remind you of what drag is. **Would a shape taking up more or less space create more drag?** (More, because there is more surface space creating more friction)
 - Hold the shapes in front of one another so students can see that even though the shapes have the same length and width (at their longest and widest points), they do NOT take up the same amount of space.
 - You can see the corners of the square around the edges of the circle and triangle. You cannot see the other shapes behind square. **The square takes up the most space and causes the most drag.**
 - You can see the edges of the circle around the edges of the triangle. You cannot see the triangle behind the circle. **The circle takes up more space than the triangle and causes more drag.**
 - You cannot see the triangle when held behind the other shapes. **The triangle takes up the least amount of space and causes the least drag.**
9. **Ask students, other than time, what else did they observe about each shaped blade dropping?** (The circle drops very haphazardly. The triangle spins very quickly and is the steadiest. These are also important observations.)
10. Ask students how a triangle or circle blade could drop more slowly than a square blade? (It would have to take up MORE space than the square). How could a triangle or circle blade take up more space? (Increase the length and width.)
11. Ask students to remind you of the next step in the EDP. (Plan)
12. Have students open to the planning portion of their notebooks. Give them 5 minutes to create a plan with their groups according to the instructions in their notebook.
13. Circulate during this time, asking students questions:
- What do you think about _____'s idea?
 - Has everyone had 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 minutes, 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 minutes 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.
16. Give each group their materials and set a timer for 15 minutes. 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 minutes, 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?
 - Instruct students to color in the bar in their notebook to create a bar graph.
18. Ask students which step is next in the engineering design process. (*improve*) Tell students that they will have 10 minutes 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.
19. Give each group their additional improve materials.

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. Prompt students to observe the difference in success between symmetrical and asymmetrical designs as they test.

If students want to use a different shape for each blade have them draw the second blade shape.

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.

20. Set a timer for 10 minutes. 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?
21. After 10 minutes, 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.
 - Instruct students to add to their bar graph in their notebooks.

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 the reflection portion of their notebooks.

Extension Activity

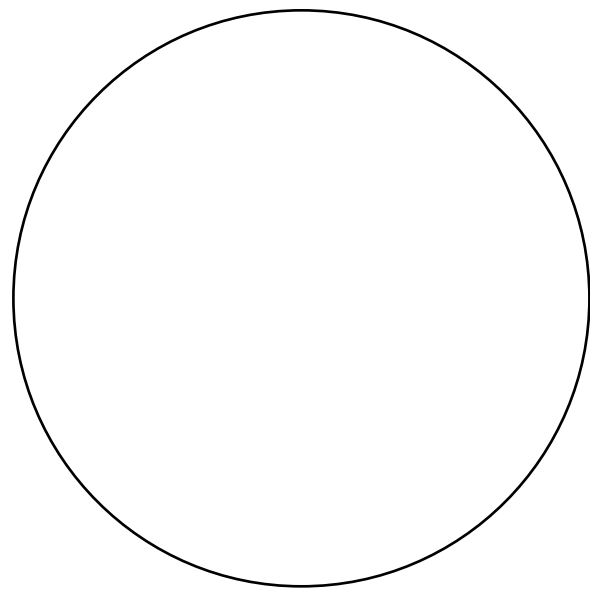
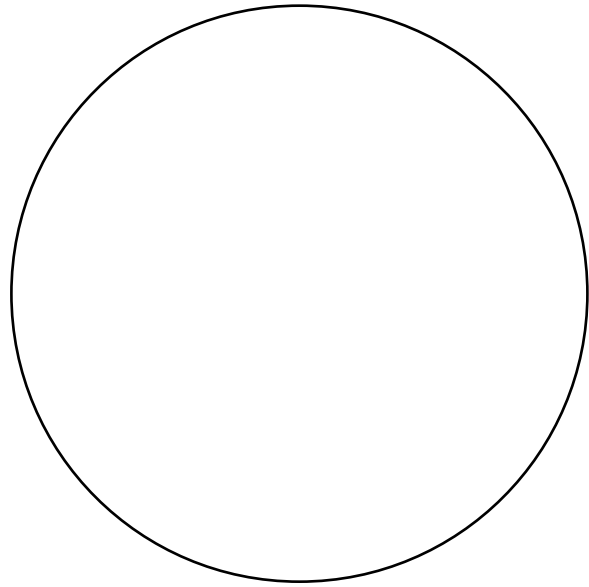
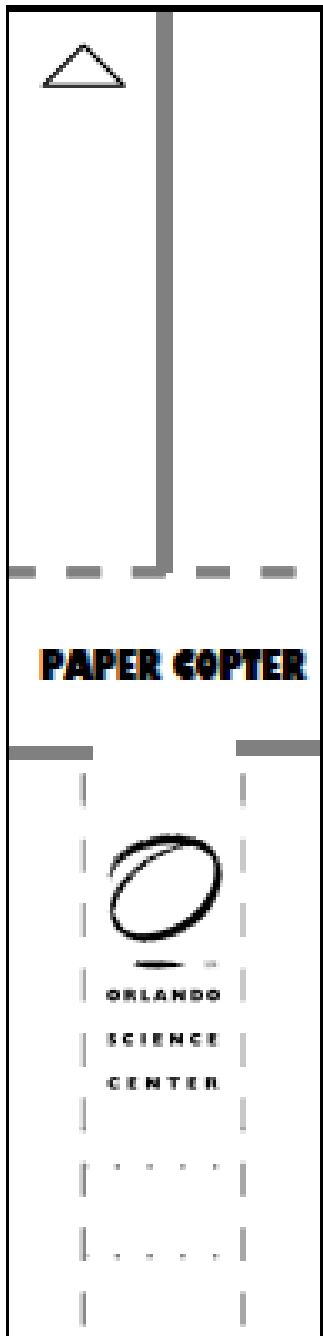
The following resource provides an additional extension and reinforcement activity.

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

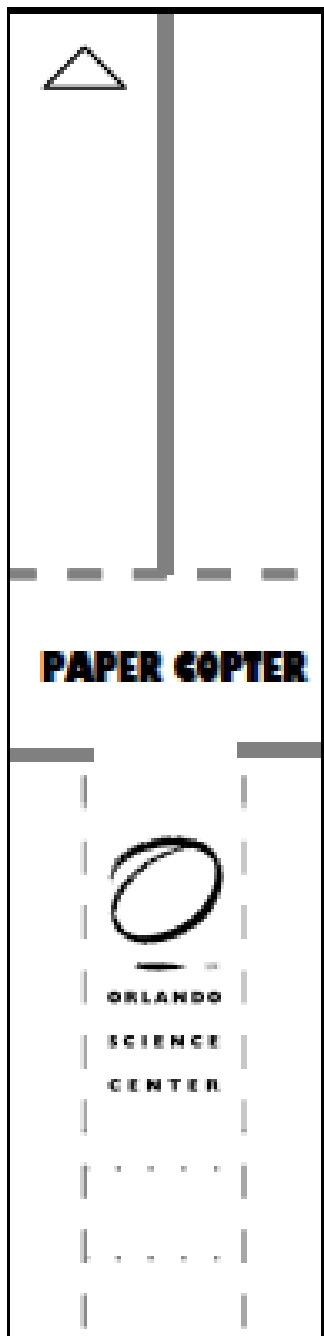
Example images of helicopters:



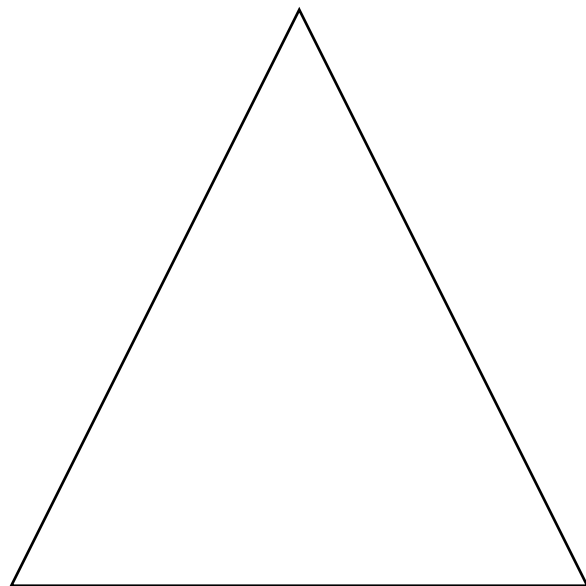
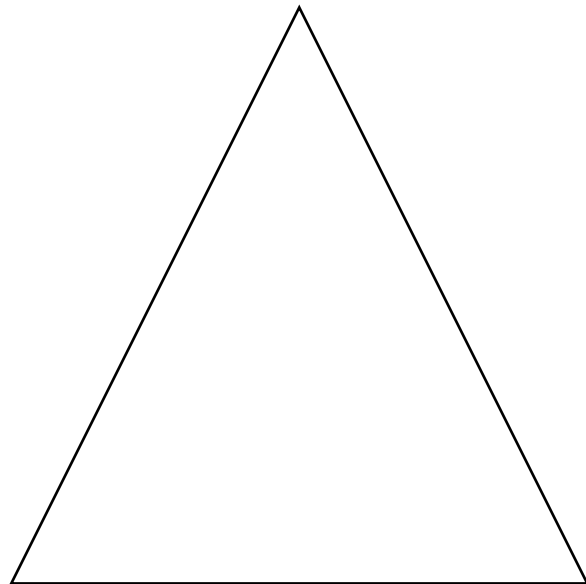
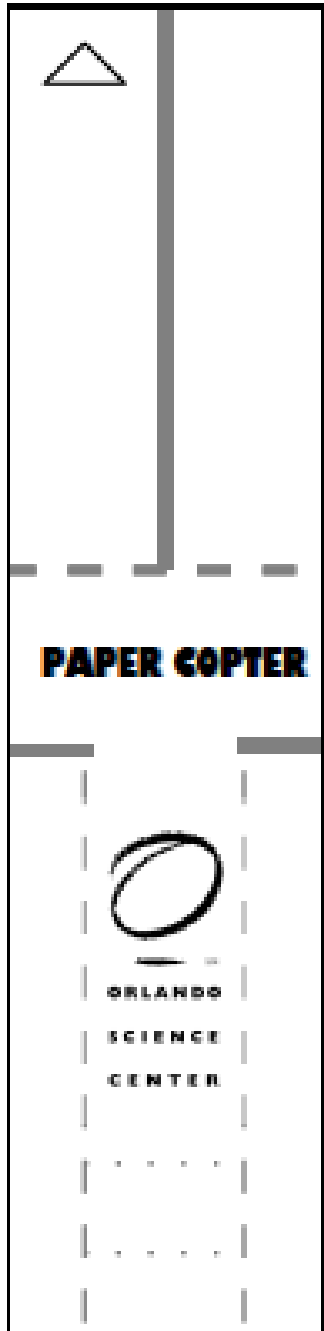
Paper copter shape test: circle



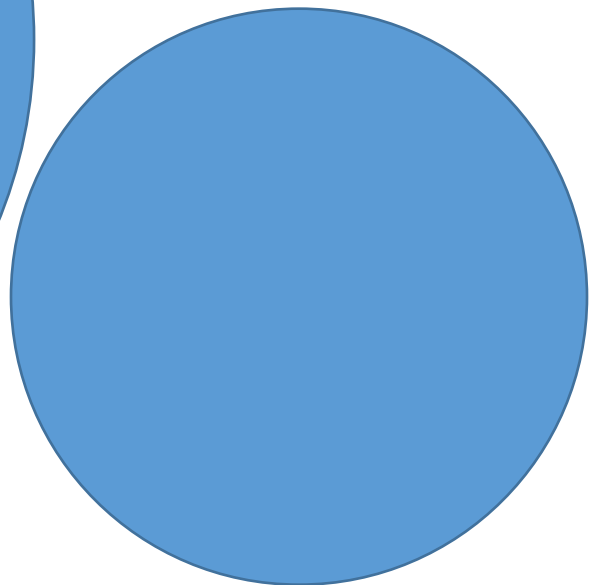
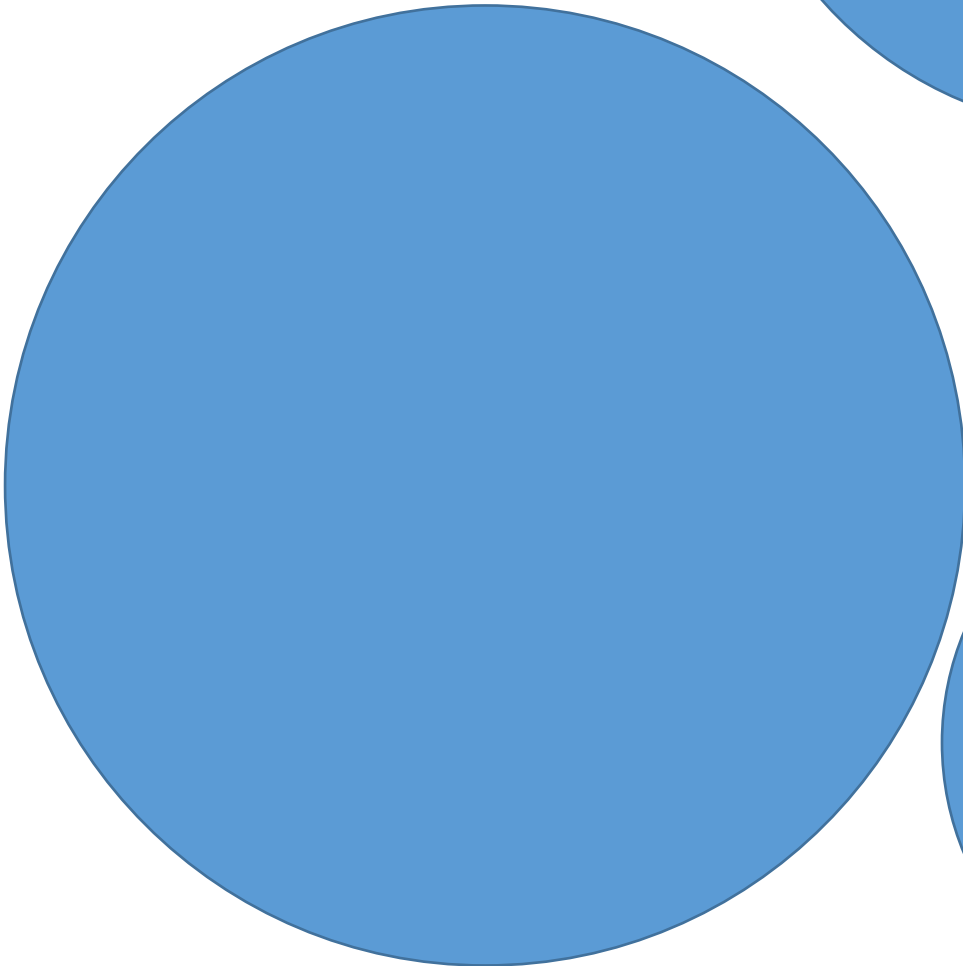
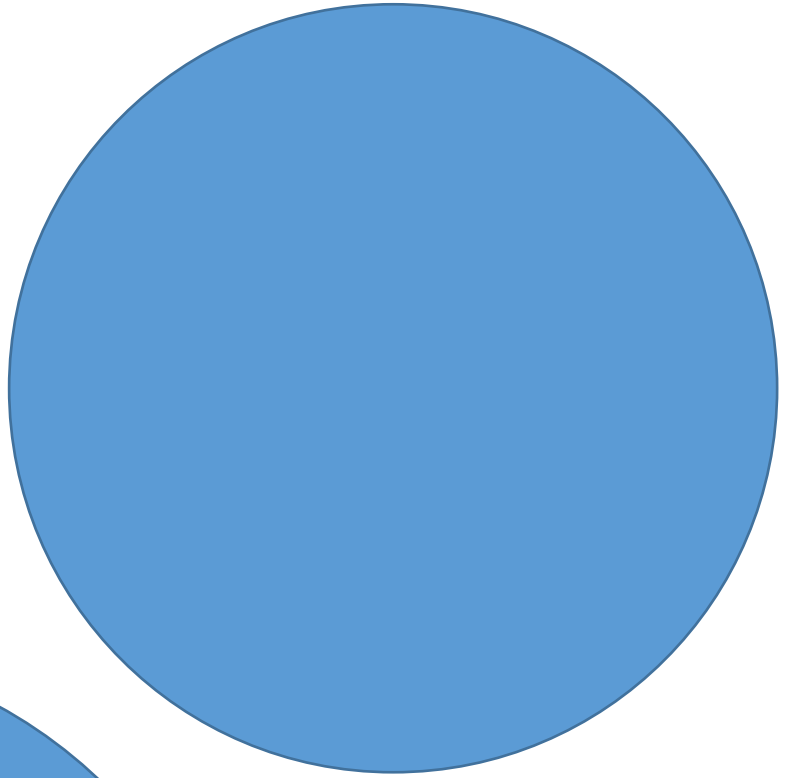
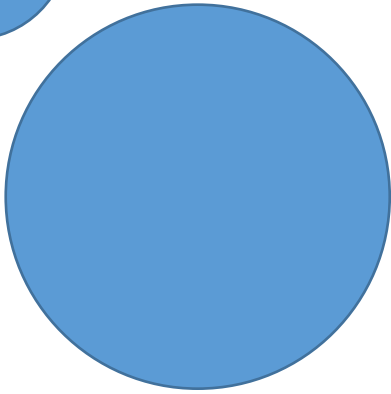
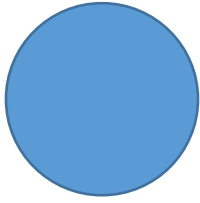
Paper copter shape test: square

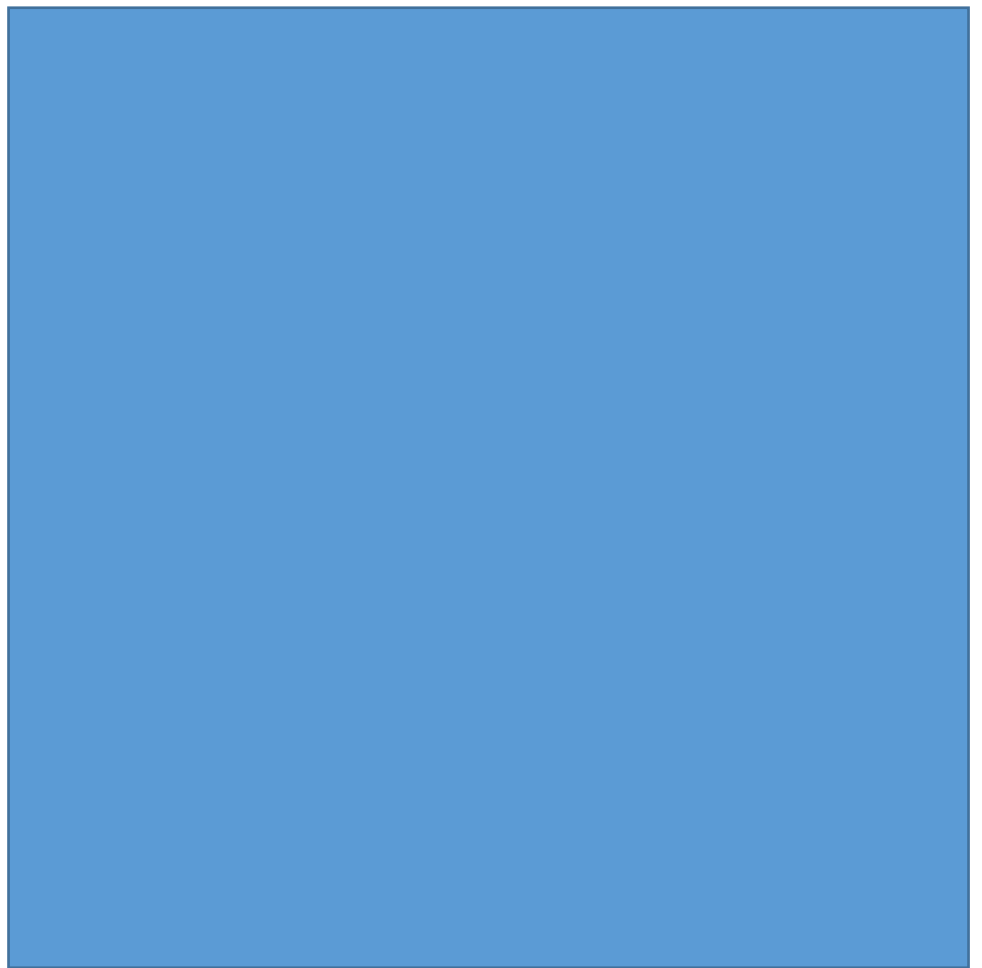
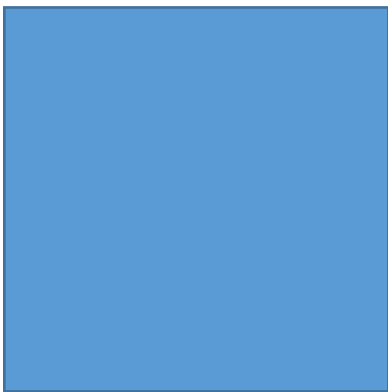
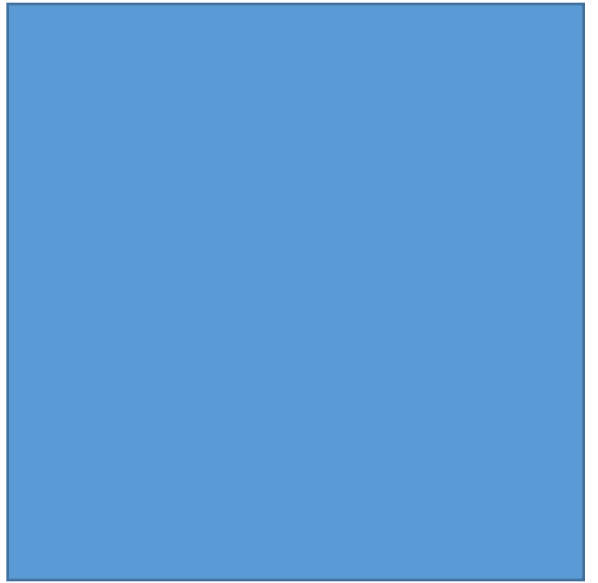
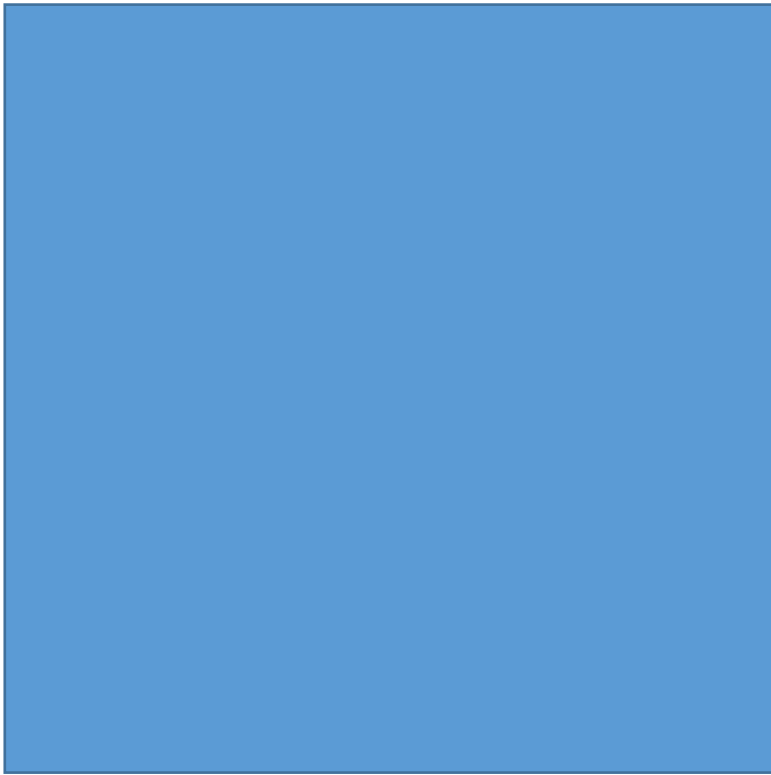


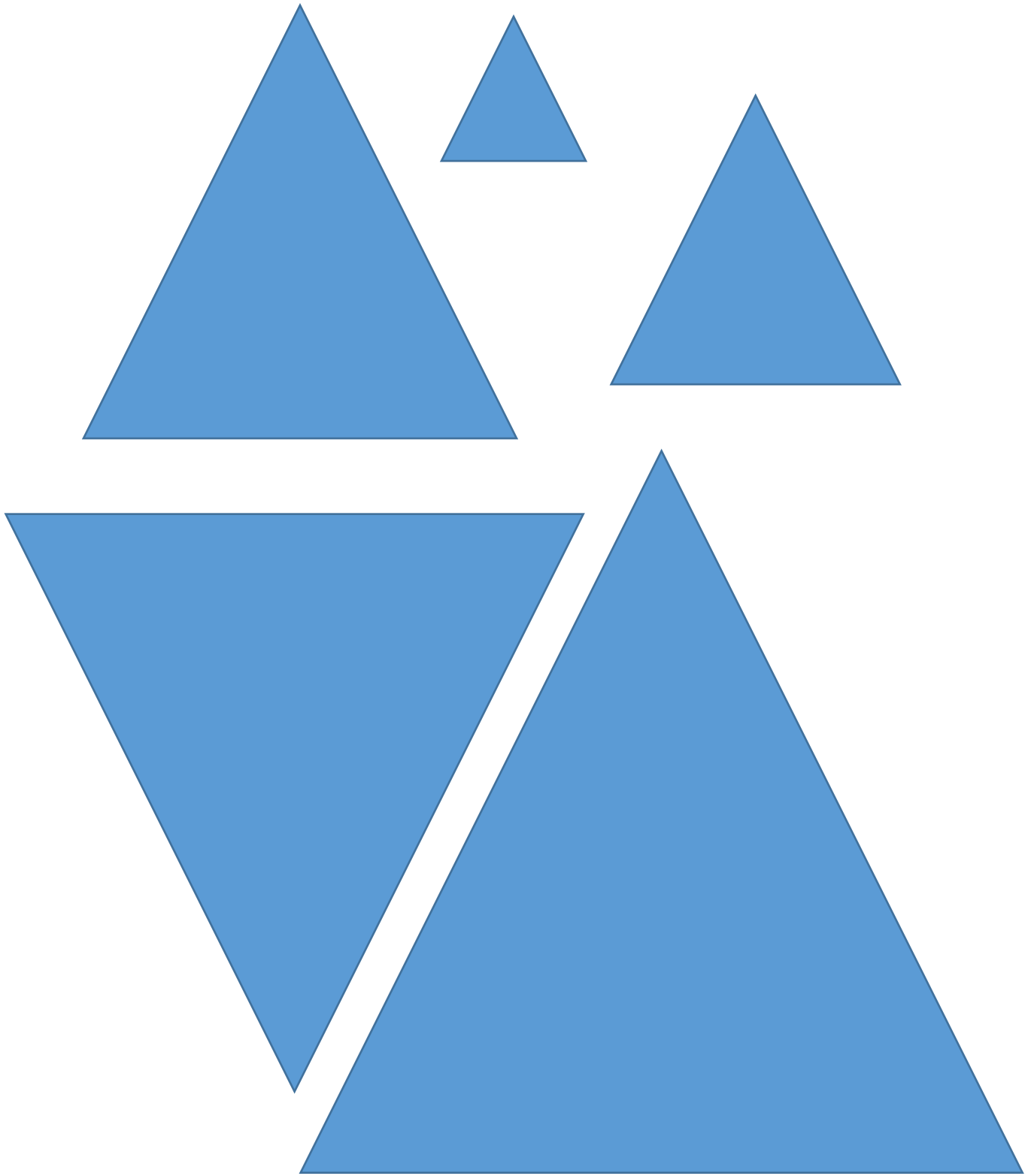
Paper copter shape test: triangle



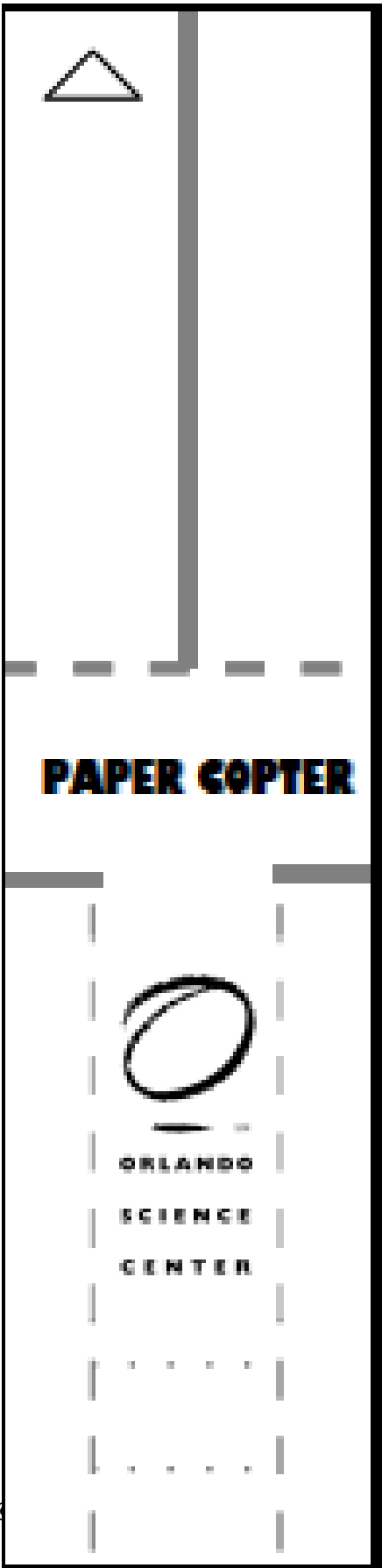
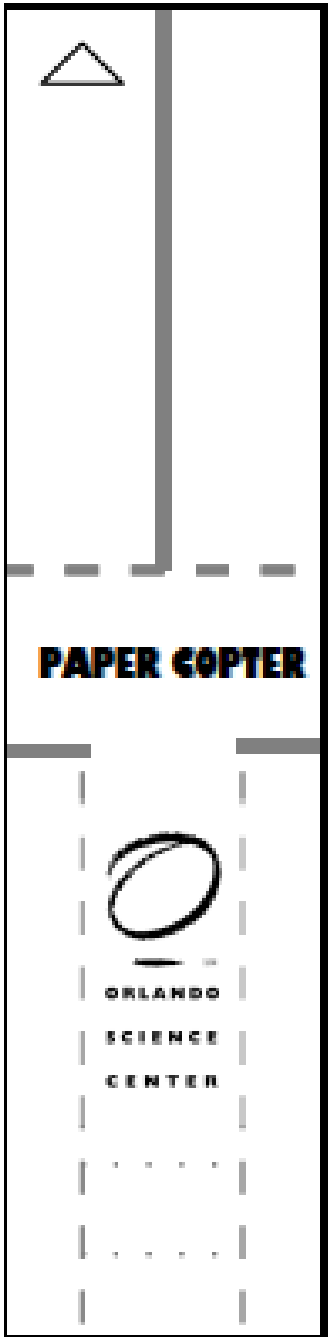
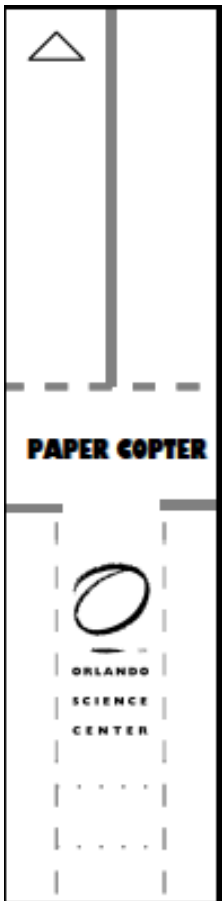
Blade Shapes Template







Paper copter Test: Size



Design a Telephone

Prep: 5 – 10 minutes

Activity: 65 minutes

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

Background

Review from 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 objects which are less dense.

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 ear drum, causing our ear drum 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 under water 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 comprehension of the following concepts, appropriate to their grade level:

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 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.

Materials

For the Class:

- Engineering Design Process (on the board or on chart paper)
- A few skeins of yarns of various thickness
- Spool of thick thread
- Spool of thin thread
- 20 of each: Small, medium, and large plastic cups
- 20 of each: Small, medium, and large paper cups
- 20 of each: Small, medium, and large Styrofoam cups
- Large bag of large, thick rubber bands
- Large bag of small, thin rubber bands

For Each Pair of 2 Students

- Bag of sample materials (see prep)

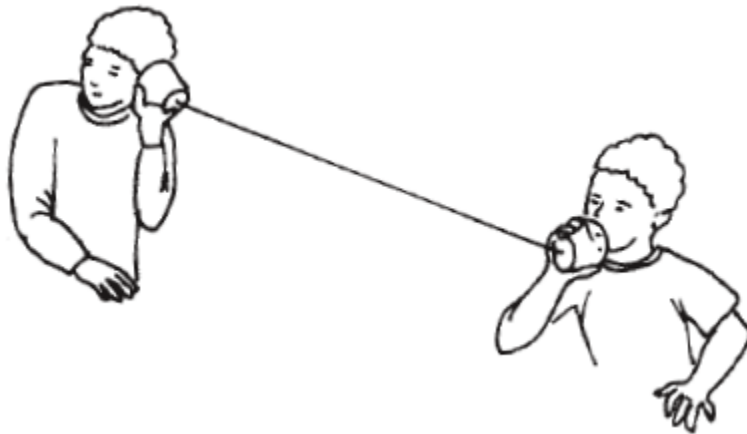
- Scissors
- 2 feet of packing tape

For Each Student

- Pencil
- Pages 32-38 of the Basic Engineering Notebook (or blank paper)

Prep

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



- Lay out materials on a table to be the “materials store.”
- Prepare one bag of sample materials per group containing:
 - 1 inch of each type of yarn and string
 - 1 large, thick rubber band
 - 1 small, thin rubber band
 - 1 of each: large, medium, and small plastic cup
 - 1 of each: large, medium, and small paper cup
 - 1 of each: large, medium, and small Styrofoam cup
- Measure a distance of 5 feet next to each group’s workspace. Place masking tape on the floor to mark the distance of 5 feet so students know how far apart to stand when testing.

Introduction (15 minutes)

- I. Review with students what they have learned about matter. Ask:
 - **What are 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 their 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 ear drum. When the vibrations are transferred to molecules next to my ear drum, it causes my ear drum to vibrate. My brain interprets this as sound.** The instructor should stand next to the third molecule and wiggle.

Teacher Tip:

Students may need more lessons on how sound travels. Demonstrate by having students listen to knocking on a door through the air, and with their ear directly against the door.

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 5 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 success of the design depends on how clearly you can hear someone on the other end of the telephone. A student will WHISPER five 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 5.

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 a materials for the string/yarn/rubber band connecting each cup, as well as how long the string/yarn/rubber band will be.

18. Time:

- Each student will have 5 minutes to imagine ideas as a group.
- Teams will then collaborate for 5 minutes 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 minutes. However, each time they finish a prototype they must score, evaluate, and then begin a new, improved prototype.
- After 25 minutes we will share our final telephones and explain the improvements we made throughout.

Activity (45 minutes)

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 minutes, 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 person’s. Tell the groups to draw their ideas in their notebooks.

4. Give students 5 minutes 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 had 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 minutes, 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 minutes 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 minutes. 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.
9. After 25 minutes, 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 5 out of 5, increase the number of words that need to be transferred clearly.

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

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 the reflection portion of their notebooks.

Extension Activity

The following resource provides an additional extension and reinforcement activity.

- "Sound Sandwich"
<https://www.exploratorium.edu/snacks/sound-sandwich>

Plant Hydrating System

Prep: 30 minutes

Activity: 120 minutes

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 peers 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 these 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 which meets the needs of the plants, animals, and other organisms living within it.

Plants are living things which 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 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 like 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 which 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 meet 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

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

- “Hydroponics: A Brief Guide to Growing Food Without Soil”
<https://extension.unr.edu/publication.aspx?PubID=2756>

- “Hydroponics: A Better Way to Grow Food”
<https://www.nps.gov/articles/hydroponics.htm>

Pre-Requisite Knowledge

Students should have comprehension of the following concepts, appropriate to their grade level:

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 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 oz
- 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 pull on an object that can change how the object is moving, and the greater a push or 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:

- “Plant Parts”
<http://www.mbgnet.net/bioplants/parts.html>

- “What do Living Things Need to Survive?”
<https://www.cpalms.org/PreviewResourceStudentTutorial/Preview/174663>

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
- 1 large roll of paper towels
- 1 roll of cling wrap

For Each Pair Students

- 1 ruler
- 1 pair of scissors
- 1 clear, plastic bottle, 2 Liter
- 3 clear, plastic cups, 18 oz.
- 3 sponges
- 1 diaper
- 1 measuring cup, in educator’s desired unit of measurement (mL or ounces)
- 15 coffee filters
- 30 cotton balls
- Felt, approximately 8 ½” x 11”
- 2 gallon-sized Ziploc bags
- 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)

For Each Student

- Pencil
- Pages 39-43 of the Basic Engineering Notebook (or blank paper)

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 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 half way 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 approximately ¼” thick.
- Create a set of sample materials for each group of students in a gallon sized Ziploc bag
 - 1 sponge
 - 1 coffee filter
 - 1 cotton ball
 - 1 square of Felt, approximately 1” x 1”
 - 1 square of paper towel, approximately 1” x 1”
- Create a set of building materials for each group in a gallon sized Ziploc bag
 - 15 coffee filters
 - 30 cotton balls
 - 5 paper towels
 - Felt, approximately 8 ½” x 11”
 - 2 sponges

Introduction (15 minutes)

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. Review each plant part and how it helps the plant get what it needs from its habitat:
 - **Roots-** absorb water containing nutrients from the soil and provide structural support
 - **Stem-** delivers water to the rest of the plant and provides structural support

- Leaves- absorb sunlight the plant needs to create food
3. Ask students if they have ever heard of a filter.
 - A **filter** is a type of technology which allows some materials to pass through but stops other materials.
 - A filter can also determine how fast a material passes through.
 - Show students the provided video of a real-life filter.
 4. Ask:
 - What would a filter need to allow to pass through for a plant to survive? (*water, air, and light*)
 - What do you think would happen if the water passed through the filter too quickly? (*The plant could drown in too much water*)
 - What do you think would happen if the water passed through the filter too slowly? (*The plant would wilt and possible die if it did not get enough water*)
 5. 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.*)
 6. 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 wants to sell a container that will meet the basic needs of plants.
 - **Goal:** Design a filter which will deliver the amount of water a plant needs in one day.
 7. 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.*)
 8. Record students’ questions on the board. Guide students to ask the following questions:
 - **How much water does the plant need to survive in a day?**
 - **What type of container will our filter be in?**
 - **What materials can we use to build our filters with?**
 - **How long do we have to create and improve our filters?**
 - **How will we know if our filter is successful?**

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.

- **How much water does the plant need to survive in one day?**

- A plant needs at least some moisture to survive, the filter must allow more than (0 ounces/0 mL) to pass through.
- A plant cannot receive too much water, or it can drown. The optimal volume of water is (4 oz.) (120 mL). Students will try to get as close to the optimal volume as possible. Have them write the volume and unit of measurement in their notebook underneath the goal.

Unit of Measurement

It is recommended that students who can add and subtract smaller numbers use ounces as the unit of measurement.

It is recommended that students who can add and subtract larger numbers use mL as the unit of measurement.

- **Filter Container:**

- Show students an empty container (prepped 2L bottle).
- Explain that the container is transparent to allow light to pass through.
- Explain that the base is where the plant will be placed (only theoretically, unless doing the extension lesson). This provides the space the plant needs to survive, so no parts of the filter can be in this area.
- 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 filter in the top part only.

Content Extension:

If doing the extension lesson provided, the teacher may research the minimum and maximum volume of water needed by the selected plant. The goal can then be changed to this range of water volume (i.e. 3-5 ounces of water).

- **Filter Materials:**

- Explain that during the imagine and plan time, students will receive a sample of materials so they can explore their properties.
- During the create time, students will receive a bag containing:
 - 15 coffee filters
 - 30 cotton balls
 - 5 paper towels
 - Felt, approximately 8 ½" x 11"
 - 2 sponges
- During the imagine time, students will receive replacements for any materials damaged in the first test.

- **Time:**
 - Students will have 15 minutes to imagine, during which they will explore absorption.
 - Students will have 10 minutes to plan.
 - Students will have 20 minutes to create.
 - Students will have 20 minutes to improve.
- **Evaluating Design Success:**
 - Have students open to the testing part of their engineering notebook.
 - Students will pour (8 oz/240 mL) of water into the top part of the container, where the filter is. If water overflows, the design will not complete the rest of testing. Students will determine how to improve the design so no water overflows.
 - All designs which did not overflow will sit for 1 day.
 - 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 passed through the filter in one day.
 - Have students find the checkmarks for measuring success:
 - If any water at all passed through, students can check off “filter allows water to pass through.”
 - Students will then check that the volume is greater than, equal to, or less than the optimal amount (4 oz./120 mL).
 - Students will then determine whether their design needs to let through more or less water and improve their design. The test is repeated after students have improved.
 - Students evaluate whether their first or second design was more successful.

Activity (90 minutes)

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 materials to see how much water it can absorb.
 - Students will determine properties which 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 in the unit of measurement students are using (ounces or mL)
3. Give students a few minutes to observe the properties of each material by looking at each one and touching it. Then have students share their observations:
 - 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 8 ounces (240 mL) of water in 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 a range (i.e. most of the students found that the sponge absorbed 1-2 ounces 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 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.

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)

8. Have students relate each material back to its absorbency, and brainstorm which properties may contribute to a materials level of absorbency. (*Observations will vary.*)
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, 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:

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).

11. Give each group a bag of sample materials and a cup of water (can re-use plastic cups or measuring cups). Provide 10 minutes 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 specific measurement, just squeeze water back into the container to see if a lot or a little or none comes out).
 - Decide which materials they will use and draw how they will use them in the planning portion of their notebook.
 - Groups who finish planning early can get their plan approved and move on to 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 of (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 move water opposite gravity's pull?

Teacher Tip:

Each group's plan must be approved before creating. When approving, the teacher should only look to see that students have drawn a plan and provide an explanation based on material properties for why they chose these materials, not for whether it is "good" or "correct."

12. After 10 minutes, 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.
13. Give each group whose plan is approved their bag of building materials, a measuring cup, scissors, a ruler, and their container (retrieve sample materials and water). Students have 20 minutes 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?
- Content Extension:**

If doing the extension lesson, ask students how they design still allows for the plant to access its other needs: Air, light, and space.
14. Provide students with a 10 minute, 5 minute, 2 minute, 1 minute and 30 second warning until testing time. Count down the last 10 seconds. At zero, students should transport their filters to a designated testing zone in the classroom.
- At the same time, each group should pour (8 oz./240 mL) into the top of their filter container. The water should be poured quickly.
 - If any water overflows:
 - Have these students complete their test 1 now in their notebook. They will need to check that water overflowed. Discuss with these students possible reasons why the water overflowed.
 - Designs that overflow will not have the absorbed amount recorded.
 - Students whose designs do not overflow can let their designs sit for 1 day.
15. After one day, have students whose designs did not overflow 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 record in their notebook.
16. Give students 5 minutes to make changes to their plan to improve. During this time, students will need replacement materials for any materials used in their first design so wetness is not a variable in testing absorbency.
17. Once a group's plan is approved, give students 20 minutes to improve. 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 minute, 5 minute, 2 minute, 1 minute and 30 second warning until testing time. Count down the last 10 seconds. Have students transport their filters to a designated testing zone in the classroom and follow the same procedures in Test 1.
19. After one day, have students whose designs did not overflow 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 record in their notebook.

Reflection (15 minutes)

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 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 minutes

Activity: 65 minutes

Science Topic: Engineering and Mathematics

Vocabulary

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

Learning Objectives: Students will...

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

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

Background

Review content in front section of this guide about the Engineering Design Process.

Resources

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 comprehension of the following concepts, appropriate to their grade level:

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

Materials

For Each Group of 4 Students

- 4 small objects (for game pieces)
- 1 ruler (with centimeters)
- 40 index cards
- 2 dice
- 4 sheets of 8 $\frac{1}{2}$ " x 11" copy paper

For Each Student

- Pencil
- Pages 44-48 of the Basic Engineering Notebook (or blank paper)

Introduction (15 minutes)

1. 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. Ask the students if they have ever played a board game? Allow the students to share their knowledge of the topic.
3. Show students images of board games in real life. If students have trouble thinking of how to create a board game, demonstrate how a player piece might move through board. Students can use dice or cards to determine how far a piece should move in the board. As a class, brainstorm how to make the path on the game board. Allow students to explore the shapes and forms that can be utilized to create the board.
4. 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.
5. 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.)*
6. 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 inches and allow four players to participate. To be engaging, players must use simple addition and subtraction to move throughout the board.

Teacher Tip:

For younger students, simplify the goal: Design a board game that is both fun and engaging. To be fun, the game board needs to have 30 spaces measured in inches and allow for four players to participate. To be engaging, players must use simple addition to move throughout the board.

7. 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.)*
8. Record students’ questions on the board. Guide students to ask the following questions:
 - **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 inches consistently to build the game board path.
 - **Mathematics:**
 - Number value should be in the ones place.
 - Each player has to perform a mathematical problem (addition or subtraction) each turn.
 - **Time:** (show the students each corresponding page in their notebooks)
 - Each student will have 5 minutes to imagine ideas in their notebooks.
 - Teams will then collaborate for 5 minutes to develop a plan.
 - Once the plan has been approved by the teacher, teams will have 15 minutes 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 minutes 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 inches), 40 index cards, and 3 sheets of 8 ½” x 11” copy paper.
 - 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.

Teacher Tip:

If students have the fine motor skills, they may also be given scissors to change the length or shape of the board.

Activity (45 minutes)

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:

 - 1 index card
 - 1 8 ½” x 11” paper
 - 1 ruler (with inches)
3. Give students 5 minutes 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 minutes, 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 person’s. Tell the groups to draw their ideas in their notebooks.
5. Give students 5 minutes to collaborate and form a plan. Circulate during this time, asking students questions:
 - What do you think about _____’s idea?
 - Has everyone had 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 minutes, check each group’s design for approval. Retrieve the sample materials (leave the ruler).
7. Ask students which step is next in the engineering design process. (*create*) Tell students that they will have 15 minutes 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 minutes. 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 minutes 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 minutes 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 minutes 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 minutes 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 minutes)

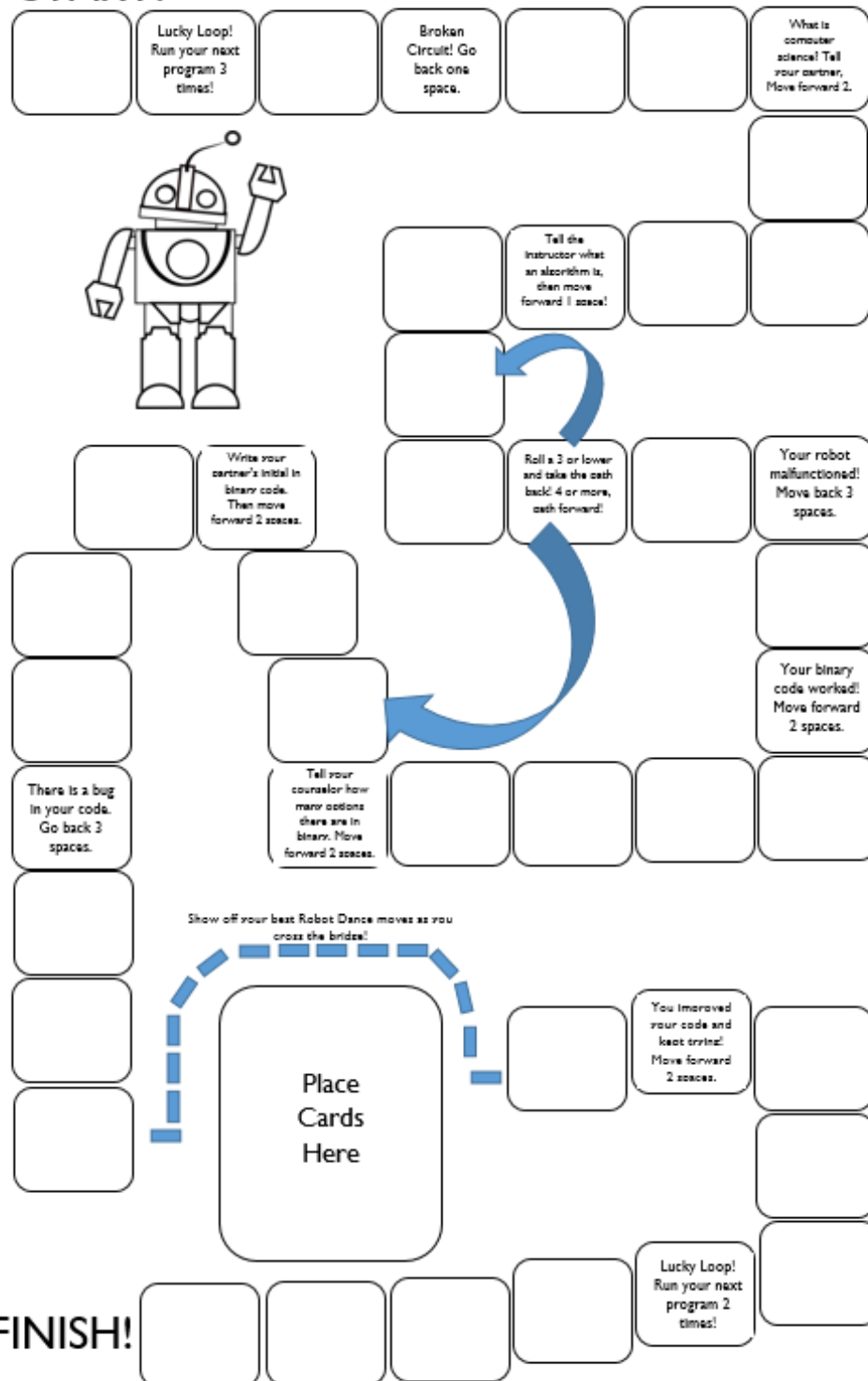
1. Ask the students:

- 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.

Example game board and game tasks:

START!



FINISH!

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Pre-Activity Standards

The following standards are embedded across all pre-activities:

K12 Standards

English Language Arts (B.E.S.T.)	
ELA.K12.EE.1.1	Cite evidence to explain and justify reasoning.
ELA.K12.EE.4.1	Use appropriate collaborative techniques and active listening skills when engaging in discussions in a variety of situations.
ELA.K12.EE.6.1	Use appropriate voice and tone when speaking or writing.
Mathematics (B.E.S.T.)	
MA.K12.MTR.1.1	Actively participate in effortful learning both individually and collectively.
MA.K12.MTR.2.1	Demonstrate understanding by representing problems in multiple ways.
MA.K12.MTR.3.1	Complete tasks with mathematical fluency.
MA.K12.MTR.4.1	Engage in discussions that reflect on the mathematical thinking of self and others.
MA.K12.MTR.5.1	Use patterns and structure to help understand and connect mathematical concepts.
MA.K12.MTR.6.1	Assess the reasonableness of solutions.
MA.K12.MTR.7.1	Apply mathematics to real-world contexts.

Kindergarten Standards

Science	
<u>Nature of Science</u>	
SC.K.N.1.1	Collaborate with a partner to collect information.
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.1.3	Keep records as appropriate -- such as pictorial records -- of investigations conducted.
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.
English Language Arts (B.E.S.T.)	
<u>Communication</u>	
ELA.K.C.1.1	Print many upper- and lowercase letters.
ELA.K.C.1.3	Using a combination of drawing, dictating, and/or writing, express opinions about a topic or text with at least one supporting reason.
ELA.K.C.1.4	Using a combination of drawing, dictating, and/or writing, provide factual information about a topic.
ELA.K.C.2.1	Present information orally using complete sentences.
ELA.K.C.3.1	Follow the rules of standard English grammar, punctuation, capitalization, and spelling appropriate to grade level.
ELA.K.C.4.1	Recall information to answer a question about a single topic.
<u>Foundational Skills</u>	
ELA.K.F.1.4	Recognize and read with automaticity grade-level high frequency words.
<u>Vocabulary</u>	
ELA.K.V.1.1	Use grade-level academic vocabulary appropriately in speaking and writing.
ELA.K.V.1.2	Ask and answer questions about unfamiliar words in grade-level content.
Mathematics (B.E.S.T.)	
<u>Measurement</u>	
MA.K.M.1.1	Identify the attributes of a single object that can be measured such as length, volume or weight.
MA.K.M.1.2	Directly compare two objects that have an attribute which can be measured in common. Express the comparison using language to describe the difference.
MA.K.M.1.3	Express the length of an object, up to 20 units long, as a whole number of lengths by laying non-standard objects end to end with no gaps or overlaps.

Kindergarten Standards, continued

Mathematics (B.E.S.T.), continued	
<u>Number Sense and Operations</u>	
MA.K.NSO.1.1	Given a group of up to 20 objects, count the number of objects in that group and represent the number of objects with a written numeral. State the number of objects in a rearrangement of that group without recounting.
MA.K.NSO.1.2	Given a number from 0 to 20, count out that many objects.
MA.K.NSO.1.3	Identify positions of objects within a sequence using the words “first,” “second,” “third,” “fourth” or “fifth.”
MA.K.NSO.1.4	Compare the number of objects from 0 to 20 in two groups using the terms less than, equal to or greater than.
MA.K.NSO.3.1	Explore addition of two whole numbers from 0 to 10, and related subtraction facts.
MA.K.NSO.3.2	Add two one-digit whole numbers with sums from 0 to 10 and subtract using related facts with procedural reliability.

1st Grade Standards

Science	
<u>Nature of Science</u>	
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.
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.
SC.1.N.1.3	Keep records as appropriate - such as pictorial and written records - of investigations conducted.
SC.1.N.1.4	Ask "how do you know?" in appropriate situations.
English Language Arts (B.E.S.T.)	
<u>Communication</u>	
ELA.1.C.1.1	Print all upper- and lowercase letters.
ELA.1.C.1.3	Write opinions about a topic or text with at least one supporting reason from a source and a sense of closure.
ELA.1.C.2.1	Present information orally using complete sentences and appropriate volume.
ELA.1.C.3.1	Follow the rules of standard English grammar, punctuation, capitalization, and spelling appropriate to grade level.
<u>Foundational Skills</u>	
ELA.1.F.1.4	Read grade-level texts with accuracy, automaticity, and appropriate prosody or expression.
<u>Vocabulary</u>	
ELA.1.V.1.1	Use grade-level academic vocabulary appropriately in speaking and writing.
ELA.1.V.1.3	Identify and use picture clues, context clues, word relationships, reference materials, and/or background knowledge to determine the meaning of unknown words.
Mathematics (B.E.S.T.)	
<u>Algebraic Reasoning</u>	
MA.1.AR.1.2	Solve addition and subtraction real-world problems using objects, drawings or equations to represent the problem.
<u>Measurement</u>	
MA.1.M.1.1	Estimate the length of an object to the nearest inch. Measure the length of an object to the nearest inch or centimeter.
MA.1.M.1.2	Compare and order the length of up to three objects using direct and indirect comparison.
<u>Number Sense and Operations</u>	
MA.1.NSO.1.2	Read numbers from 0 to 100 written in standard form, expanded form and word form. Write numbers from 0 to 100 using standard form and expanded form.
MA.1.NSO.2.2	Add two whole numbers with sums from 0 to 20, and subtract using related facts with procedural reliability.

2nd Grade Standards

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.
English Language Arts (B.E.S.T.)	
<u>Communication</u>	
ELA.2.C.1.1	Demonstrate legible printing skills.
ELA.2.C.1.3	Write opinions about a topic or text with reasons supported by details from a source, use transitions, and provide a conclusion.
ELA.2.C.2.1	Present information orally using complete sentences, appropriate volume, and clear pronunciation.
ELA.2.C.3.1	Follow the rules of standard English grammar, punctuation, capitalization, and spelling appropriate to grade level.
<u>Foundational Skills</u>	
ELA.2.F.1.4	Read grade-level texts with accuracy, automaticity, and appropriate prosody or expression.
<u>Vocabulary</u>	
ELA.2.V.1.1	Use grade-level academic vocabulary appropriately in speaking and writing.
ELA.2.V.1.3	Identify and use context clues, word relationships, reference materials, and/or background knowledge to determine the meaning of unknown words
Mathematics (B.E.S.T.)	
<u>Algebraic Reasoning</u>	
MA.2.AR.1.1	Solve one- and two-step addition and subtraction real-world problems.
<u>Measurement</u>	
MA.2.M.1.1	Estimate and measure the length of an object to the nearest inch, foot, yard, centimeter or meter by selecting and using an appropriate tool.
MA.2.M.1.2	Measure the lengths of two objects using the same unit and determine the difference between their measurements.
<u>Number Sense and Operations</u>	
MA.2.NSO.1.1	Read and write numbers from 0 to 1,000 using standard form, expanded form and word form.
MA.2.NSO.2.3	Add two whole numbers with sums up to 100 with procedural reliability. Subtract a whole number from a whole number, each no larger than 100, with procedural reliability.
MA.2.NSO.2.4	Explore the addition of two whole numbers with sums up to 1,000. Explore the subtraction of a whole number from a whole number, each no larger than 1,000.

3rd Grade Standards

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.
English Language Arts (B.E.S.T.)	
<u>Communication</u>	
ELA.3.C.1.3	Write opinions about a topic or text, include reasons supported by details from one or more sources, use transitions, and provide a conclusion.
ELA.3.C.2.1	Present information orally, in a logical sequence, using nonverbal cues, appropriate volume, and clear pronunciation.
ELA.3.C.3.1	Follow the rules of standard English grammar, punctuation, capitalization, and spelling appropriate to grade level.
<u>Foundational Skills</u>	
ELA.3.F.1.4	Read grade-level texts with accuracy, automaticity, and appropriate prosody or expression.
<u>Vocabulary</u>	
ELA.3.V.1.1	Use grade-level academic vocabulary appropriately in speaking and writing.
ELA.3.V.1.2	Identify and apply knowledge of common Greek and Latin roots, base words, and affixes to determine the meaning of unfamiliar words in grade-level content.
ELA.3.V.1.3	Use context clues, figurative language, word relationships, reference materials, and/or background knowledge to determine the meaning of multiple-meaning and unknown words and phrases, appropriate to grade level.
Mathematics (B.E.S.T.)	
<u>Algebraic Reasoning</u>	
MA.3.AR.1.1	Apply the distributive property to multiply a one-digit number and two-digit number. Apply properties of multiplication to find a product of one-digit whole numbers.
MA.3.AR.1.2	Solve one- and two-step real-world problems involving any of four operations with whole numbers.
<u>Measurement</u>	
MA.3.M.1.1	Select and use appropriate tools to measure the length of an object, the volume of liquid within a beaker and temperature.
MA.3.M.1.2	Solve real-world problems involving any of the four operations with whole-number lengths, masses, weights, temperatures or liquid volumes.
<u>Number Sense and Operations</u>	
MA.3.NSO.1.1	Read and write numbers from 0 to 10,000 using standard form, expanded form and word form.
MA.3.NSO.2.1	Add and subtract multi-digit whole numbers including using a standard algorithm with procedural fluency.
MA.3.NSO.2.2	Explore multiplication of two whole numbers with products from 0 to 144, and related division facts.
MS.3.NSO.2.3	Multiply a one-digit whole number by a multiple of 10, up to 90, or a multiple of 100, up to 900, with procedural reliability.
MS.3.NSO.2.4	Multiply two whole numbers from 0 to 12 and divide using related facts with procedural reliability.

4th Grade Standards

Science	
<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.
English Language Arts (B.E.S.T.)	
<u>Communication</u>	
ELA.4.C.1.3	Write to make a claim supporting a perspective with logical reasons, using evidence from multiple sources, elaboration, and an organizational structure with transitions.
ELA.4.C.2.1	Present information orally, in a logical sequence, using nonverbal cues, appropriate volume, and clear pronunciation.
ELA.4.C.3.1	Follow the rules of standard English grammar, punctuation, capitalization, and spelling appropriate to grade level.
<u>Foundational Skills</u>	
ELA.4.F.1.4	Read grade-level texts with accuracy, automaticity, and appropriate prosody or expression.
<u>Vocabulary</u>	
ELA.4.V.1.1	Use grade-level academic vocabulary appropriately in speaking and writing.
ELA.4.V.1.2	Apply knowledge of common Greek and Latin roots, base words, and affixes to determine the meaning of unfamiliar words in grade-level content.
ELA.4.V.1.3	Use context clues, figurative language, word relationships, reference materials, and/or background knowledge to determine the meaning of multiple-meaning and unknown words and phrases, appropriate to grade level.
Mathematics (B.E.S.T.)	
<u>Algebraic Reasoning</u>	
MA.4.AR.1.1	Solve real-world problems involving multiplication and division of whole numbers including problems in which remainders must be interpreted within the context.
<u>Measurement</u>	
MA.4.M.1.1	Select and use appropriate tools to measure attributes of objects.
MA.4.M.1.2	Convert within a single system of measurement using the units: yards, feet, inches; kilometers, meters, centimeters, millimeters; pounds, ounces; kilograms, grams; gallons, quarts, pints, cups; liter, milliliter; and hours, minutes, seconds.
<u>Number Sense and Operations</u>	
MA.4.NSO.1.1	Express how the value of a digit in a multi-digit whole number changes if the digit moves one place to the left or right.
MA.4.NSO.2.2	Multiply two whole numbers, up to three digits by up to two digits, with procedural reliability.
MA.4.NSO.2.3	Multiply two whole numbers, each up to two digits, including using a standard algorithm with procedural fluency.
MA.4.NSO.2.5	Explore the multiplication and division of multi-digit whole numbers using estimation, rounding and place value.

5th Grade Standards

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.
English Language Arts (B.E.S.T.)	
<u>Communication</u>	
ELA.5.C.1.3	Write to make a claim supporting a perspective with logical reasons, relevant evidence from sources, elaboration, and an organizational structure with varied transitions.
ELA.5.C.2.1	Present information orally, in a logical sequence, using nonverbal cues, appropriate volume, clear pronunciation, and appropriate pacing.
ELA.5.C.3.1	Follow the rules of standard English grammar, punctuation, capitalization, and spelling appropriate to grade level.
<u>Foundational Skills</u>	
ELA.5.F.1.4	Read grade-level texts with accuracy, automaticity, and appropriate prosody or expression.
<u>Vocabulary</u>	
ELA.5.V.1.1	Use grade-level academic vocabulary appropriately in speaking and writing.
ELA.5.V.1.2	Apply knowledge of Greek and Latin roots and affixes, recognizing the connection between affixes and parts of speech, to determine the meaning of unfamiliar words in grade-level content.
ELA.5.V.1.3	Use context clues, figurative language, word relationships, reference materials, and/or background knowledge to determine the meaning of multiple-meaning and unknown words and phrases, appropriate to grade level.
Mathematics (B.E.S.T.)	
<u>Algebraic Reasoning</u>	
MA.5.AR.1.1	Solve multi-step real-world problems involving any combination of the four operations with whole numbers, including problems in which remainders must be interpreted within the context.
<u>Measurement</u>	
MA.5.M.1.1	Solve multi-step real-world problems that involve converting measurement units to equivalent measurements within a single system of measurement.
<u>Number Sense and Operations</u>	
MA.5.NSO.1.5	Round multi-digit numbers with decimals to the thousandths to the nearest hundredth, tenth or whole number.
MA.5.NSO.2.1	Multiply multi-digit whole numbers including using a standard algorithm with procedural fluency.

In addition to the standards listed above, the following are embedded in individual pre-activities:

Design a 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.
	Mathematics (B.E.S.T.)	
	<u>Data Analysis and Probability</u>	
	MA.K.DP.1.1	Collect and sort objects into categories and compare the categories by counting the objects in each category. Report the results verbally, with a written numeral or with drawings.
	<u>Geometric Reasoning</u>	
I	MA.K.GR.1.1	Identify two- and three-dimensional figures regardless of their size or orientation. Figures are limited to circles, triangles, rectangles, squares, spheres, cubes, cones and cylinders.
	MA.K.GR.1.2	Compare two-dimensional figures based on their similarities, differences and positions. Sort two-dimensional figures based on their similarities and differences. Figures are limited to circles, triangles, rectangles and squares.
	MA.K.GR.1.3	Compare three-dimensional figures based on their similarities, differences and positions. Sort three-dimensional figures based on their similarities and differences. Figures are limited to spheres, cubes, cones and cylinders.
	MA.K.GR.1.4	Find real-world objects that can be modeled by a given two- or three-dimensional figure. Figures are limited to circles, triangles, rectangles, squares, spheres, cubes, cones and cylinders.
	MA.K.GR.1.5	Combine two-dimensional figures to form a given composite figure. Figures used to form a composite shape are limited to triangles, rectangles and squares.
	<u>Measurement</u>	
	MA.K.M.1.3	Express the length of an object, up to 20 units long, as a whole number of lengths by laying non-standard objects end to end with no gaps or overlaps.
	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.I.P.13.1	Demonstrate that the way to change the motion of an object is by applying a push or a pull.
	Mathematics (B.E.S.T.)	
	<u>Data Analysis and Probability</u>	
	MA.I.DP.1.1	Collect data into categories and represent the results using tally marks or pictographs.
	<u>Geometric Reasoning</u>	
	MA.I.GR.1.1	Identify, compare and sort two- and three-dimensional figures based on their defining attributes. Figures are limited to circles, semi-circles, triangles, rectangles, squares, trapezoids, hexagons, spheres, cubes, rectangular prisms, cones and cylinders.
	MA.I.GR.1.3	Compose and decompose two- and three-dimensional figures. Figures are limited to semi-circles, triangles, rectangles, squares, trapezoids, hexagons, cubes, rectangular prisms, cones and cylinders.
	MA.I.GR.1.4	Given a real-world object, identify parts that are modeled by two- and three-dimensional figures. Figures are limited to semi-circles, triangles, rectangles, squares and hexagons, spheres, cubes, rectangular prisms, cones and cylinders.

Design a Scaffolding System (continued)

2	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.
	Mathematics (B.E.S.T.)
	<u>Data Analysis and Probability</u> MA.2.DP.1.1 Collect, categorize and represent data using tally marks, tables, pictographs or bar graphs. Use appropriate titles, labels and units. <u>Geometric Reasoning</u> MA.2.GR.1.1 Identify and draw two-dimensional figures based on their defining attributes. Figures are limited to triangles, rectangles, squares, pentagons, hexagons and octagons. MA.2.GR.1.2 Categorize two-dimensional figures based on the number and length of sides, number of vertices, whether they are closed or not and whether the edges are curved or straight.
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.
	Mathematics (B.E.S.T.)
	<u>Data Analysis and Probability</u> MA.3.DP.1.1 Collect and represent numerical and categorical data with whole-number values using tables, scaled pictographs, scaled bar graphs or line plots. Use appropriate titles, labels and units. <u>Geometric Reasoning</u> MA.3.GR.1.2 Identify and draw quadrilaterals based on their defining attributes. Quadrilaterals include parallelograms, rhombi, rectangles, squares and trapezoids. MA.3.GR.2.1 Explore area as an attribute of a two-dimensional figure by covering the figure with unit squares without gaps or overlaps. Find areas of rectangles by counting unit squares. MA.3.GR.2.2 Find the area of a rectangle with whole-number side lengths using a visual model and a multiplication formula. MA.3.GR.2.3 Solve mathematical and real-world problems involving the perimeter and area of rectangles with whole-number side lengths using a visual model and a formula. MA.3.GR.2.4 Solve mathematical and real-world problems involving the perimeter and area of composite figures composed of non-overlapping rectangles with whole-number side lengths.
4	Science
	<u>Physical Science</u> 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. SC.4.P.10.2 Investigate and describe that energy has the ability to cause motion or create change.
	Mathematics (B.E.S.T.)
	<u>Data Analysis and Probability</u> MA.4.DP.1.1 Collect and represent numerical data, including fractional values, using tables, stem-and-leaf plots or line plots. <u>Measurement</u> MA.4.GR.2.1 Solve perimeter and area mathematical and real-world problems, including problems with unknown sides, for rectangles with whole-number side lengths. MA.4.GR.2.2 Solve problems involving rectangles with the same perimeter and different areas or with the same area and different perimeters.

Design a Scaffolding System (continued)

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.
	Mathematics (B.E.S.T.)	
	<u>Data Analysis and Probability</u>	
	MA.5.DP.1.1	Collect and represent numerical data, including fractional and decimal values, using tables, line graphs or line plots.
	<u>Measurement</u>	
	MA.5.GR.1.1	Classify triangles or quadrilaterals into different categories based on shared defining attributes. Explain why a triangle or quadrilateral would or would not belong to a category.

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.
	Mathematics (B.E.S.T.) <u>Data Analysis and Probability</u> MA.K.DP.1.1 Collect and sort objects into categories and compare the categories by counting the objects in each category. Report the results verbally, with a written numeral or with drawings.
1	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.13.1 Demonstrate that the way to change the motion of an object is by applying a push or a pull.
	Mathematics (B.E.S.T.) <u>Data Analysis and Probability</u> MA.1.DP.1.1 Collect data into categories and represent the results using tally marks or pictographs.
2	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.
	Mathematics (B.E.S.T.) <u>Data Analysis and Probability</u> MA.2.DP.1.1 Collect, categorize and represent data using tally marks, tables, pictographs or bar graphs. Use appropriate titles, labels and units.
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.
	Mathematics (B.E.S.T.) <u>Data Analysis and Probability</u> MA.3.DP.1.1 Collect and represent numerical and categorical data with whole-number values using tables, scaled pictographs, scaled bar graphs or line plots. Use appropriate titles, labels and units.

Design a Roller Coaster (continued)

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.
	Mathematics (B.E.S.T.) <u>Data Analysis and Probability</u> MA.4.DP.1.1 Collect and represent numerical data, including fractional values, using tables, stem-and-leaf plots or line plots. <u>Measurement</u> MA.4.M.2.1 Solve two-step real-world problems involving distances and intervals of time using any combination of the four operations. <u>Number Sense and Operations</u> MA.4.NSO.2.4 Divide a whole number up to four digits by a one-digit whole number with procedural reliability. Represent remainders as fractional parts of the divisor.
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.
	Mathematics (B.E.S.T.) <u>Data Analysis and Probability</u> MA.5.DP.1.1 Collect and represent numerical data, including fractional and decimal values, using tables, line graphs or line plots. <u>Number Sense and Operations</u> MA.5.NSO.2.2 Divide multi-digit whole numbers, up to five digits by two digits, including using a standard algorithm with procedural fluency. Represent remainders as fractions.

Design Play Dough

K	Science
	<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.
1	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.
2	Mathematics (B.E.S.T.)
	<u>Fractions</u>
	MA.1.FR.1.1 Partition circles and rectangles into two and four equal-sized parts. Name the parts of the whole using appropriate language including halves or fourths.
3	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.
3	Mathematics (B.E.S.T.)
	<u>Fractions</u>
	MA.2.FR.1.1 Partition circles and rectangles into two, three or four equal-sized parts. Name the parts using appropriate language, and describe the whole as two halves, three thirds or four fourths. MA.2.FR.1.2 Partition rectangles into two, three or four equal-sized parts in two different ways showing that equal-sized parts of the same whole may have different shapes.
3	<u>Measurement</u>
	MA.2.M.1.3 Solve one- and two-step real-world measurement problems involving addition and subtraction of lengths given in the same units.
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.
3	Mathematics (B.E.S.T.)
	<u>Fractions</u>
	MA.3.FR.1.1 Represent and interpret unit fractions in the form $\frac{1}{n}$ as the quantity formed by one part when a whole is partitioned into n equal parts. MA.3.FR.1.2 Represent and interpret fractions greater than one, in the form of $\frac{m}{n}$ as the result of adding the unit fraction $\frac{1}{n}$ to itself m times. MA.3.FR.1.3 Read and write fractions, including fractions greater than one, using standard form, numeral-word form and word form.

Design Play Dough (continued)

4	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.
	Mathematics (B.E.S.T.)	
	<u>Fractions</u>	
5	MA.4.FR.1.1	Model and express a fraction, including mixed numbers and fractions greater than one, with the denominator 10 as an equivalent fraction with the denominator 100.
	MA.4.FR.1.2	Use decimal notation to represent fractions with denominators of 10 or 100, including mixed numbers and fractions greater than 1, and use fractional notation with denominators of 10 or 100 to represent decimals.
	MA.4.FR.1.3	Identify and generate equivalent fractions, including fractions greater than one. Describe how the numerator and denominator are affected when the equivalent fraction is created.
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.
	Mathematics (B.E.S.T.)	
	<u>Fractions</u>	
	MA.5.FR.1.1	Given a mathematical or real-world problem, represent the division of two whole numbers as a fraction.

Water Runoff Reduction System

K	Science
	<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.
	Mathematics (B.E.S.T.)
	<u>Data Analysis and Probability</u> MA.K.DP.1.1 Collect and sort objects into categories and compare the categories by counting the objects in each category. Report the results verbally, with a written numeral or with drawings.
1	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.
	Mathematics (B.E.S.T.)
2	<u>Data Analysis and Probability</u> MA.1.DP.1.1 Collect data into categories and represent the results using tally marks or pictographs.
	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> 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.
3	Mathematics (B.E.S.T.)
	<u>Data Analysis and Probability</u> MA.2.DP.1.1 Collect, categorize and represent data using tally marks, tables, pictographs or bar graphs. Use appropriate titles, labels and units.
	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.
4	Mathematics (B.E.S.T.)
	<u>Data Analysis and Probability</u> MA.3.DP.1.1 Collect and represent numerical and categorical data with whole-number values using tables, scaled pictographs, scaled bar graphs or line plots. Use appropriate titles, labels and units.
	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).
4	<u>Life Science</u> SC.4.L.17.4 Recognize ways plants and animals, including humans, can impact the environment.

Water Runoff Reduction System (continued)

4	Mathematics (B.E.S.T.)	
	<u>Data Analysis and Probability</u>	
	MA.4.DP.1.1	Collect and represent numerical data, including fractional values, using tables, stem-and-leaf plots or line plots.
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.
	Mathematics (B.E.S.T.)	
	<u>Data Analysis and Probability</u>	
	MA.5.DP.1.1	Collect and represent numerical data, including fractional and decimal values, using tables, line graphs or line plots.

Create a Zip Line

K	Mathematics (B.E.S.T.)
	<u>Data Analysis and Probability</u> MA.K.DP.1.1 Collect and sort objects into categories and compare the categories by counting the objects in each category. Report the results verbally, with a written numeral or with drawings.
1	Mathematics (B.E.S.T.)
	<u>Data Analysis and Probability</u> MA.1.DP.1.1 Collect data into categories and represent the results using tally marks or pictographs.
2	Mathematics (B.E.S.T.)
	<u>Data Analysis and Probability</u> MA.2.DP.1.1 Collect, categorize and represent data using tally marks, tables, pictographs or bar graphs. Use appropriate titles, labels and units.
3	Mathematics (B.E.S.T.)
	<u>Data Analysis and Probability</u> MA.3.DP.1.1 Collect and represent numerical and categorical data with whole-number values using tables, scaled pictographs, scaled bar graphs or line plots. Use appropriate titles, labels and units.
4	Mathematics (B.E.S.T.)
	<u>Data Analysis and Probability</u> MA.4.DP.1.1 Collect and represent numerical data, including fractional values, using tables, stem-and-leaf plots or line plots.
5	Mathematics (B.E.S.T.)
	<u>Data Analysis and Probability</u> MA.5.DP.1.1 Collect and represent numerical data, including fractional and decimal values, using tables, line graphs or line plots.

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.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.12.1 Investigate that things move in different ways, such as fast, slow, etc.
	Mathematics (B.E.S.T.) <u>Geometric Reasoning</u> MA.K.GR.1.1 Identify two- and three-dimensional figures regardless of their size or orientation. Figures are limited to circles, triangles, rectangles, squares, spheres, cubes, cones and cylinders. MA.K.GR.1.2 Compare two-dimensional figures based on their similarities, differences and positions. Sort two-dimensional figures based on their similarities and differences. Figures are limited to circles, triangles, rectangles and squares. MA.K.GR.1.3 Compare three-dimensional figures based on their similarities, differences and positions. Sort three-dimensional figures based on their similarities and differences. Figures are limited to spheres, cubes, cones and cylinders.
1	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.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. 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.
	Mathematics (B.E.S.T.) <u>Data Analysis and Probability</u> MA.1.DP.1.1 Collect data into categories and represent the results using tally marks or pictographs. <u>Geometric Reasoning</u> MA.1.GR.1.1 Identify, compare and sort two- and three-dimensional figures based on their defining attributes. Figures are limited to circles, semi-circles, triangles, rectangles, squares, trapezoids, hexagons, spheres, cubes, rectangular prisms, cones and cylinders.
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.13.3 Recognize that objects are pulled toward the ground unless something holds them up.
	Mathematics (B.E.S.T.) <u>Data Analysis and Probability</u> MA.2.DP.1.1 Collect, categorize and represent data using tally marks, tables, pictographs or bar graphs. Use appropriate titles, labels and units.
	<u>Geometric Reasoning</u> MA.2.GR.1.1 Identify and draw two-dimensional figures based on their defining attributes. Figures are limited to triangles, rectangles, squares, pentagons, hexagons and octagons. MA.2.GR.1.2 Categorize two-dimensional figures based on the number and length of sides, number of vertices, whether they are closed or not and whether the edges are curved or straight.
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.

Design a Paper-Copter (continued)

3	<u>Physical Science</u>	
	SC.3.P.8.3	Compare materials and objects according to properties such as size, shape, color, texture, and hardness.
	SC.3.P.10.2	Recognize that energy has the ability to cause motion or create change.
	Mathematics (B.E.S.T.)	
	<u>Data Analysis and Probability</u>	
	MA.3.DP.1.1	Collect and represent numerical and categorical data with whole-number values using tables, scaled pictographs, scaled bar graphs or line plots. Use appropriate titles, labels and units.
	<u>Geometric Reasoning</u>	
	MA.3.GR.1.2	Identify and draw quadrilaterals based on their defining attributes. Quadrilaterals include parallelograms, rhombi, rectangles, squares and trapezoids.
	MA.3.GR.2.1	Explore area as an attribute of a two-dimensional figure by covering the figure with unit squares without gaps or overlaps. Find areas of rectangles by counting unit squares.
	MA.3.GR.2.2	Find the area of a rectangle with whole-number side lengths using a visual model and a multiplication formula.
4	MA.3.GR.2.3	Solve mathematical and real-world problems involving the perimeter and area of rectangles with whole-number side lengths using a visual model and a formula.
	MA.3.GR.2.4	Solve mathematical and real-world problems involving the perimeter and area of composite figures composed of non-overlapping rectangles with whole-number side lengths.
	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.
	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.
	Mathematics (B.E.S.T.)	
	<u>Measurement and Data</u>	
	MA.4.GR.2.1	Solve perimeter and area mathematical and real-world problems, including problems with unknown sides, for rectangles with whole-number side lengths.
5	MA.4.GR.2.2	Solve problems involving rectangles with the same perimeter and different areas or with the same area and different perimeters.
	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.
	Mathematics (B.E.S.T.)	
	<u>Geometric Reasoning</u>	
	MA.5.GR.1.2	Identify and classify three-dimensional figures into categories based on their defining attributes. Figures are limited to right pyramids, right prisms, right circular cylinders, right circular cones and spheres.
	MA.5.GR.2.1	Find the perimeter and area of a rectangle with fractional or decimal side lengths using visual models and formulas.

Design a Telephone

K	Science
	<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.10.1 Observe that things that make sound vibrate.
1	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.
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.
3	Science
	<u>Physical Science</u> SC.3.P.8.3 Compare materials and objects according to properties such as size, shape, color, texture, and hardness. 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.
4	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. 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.10.3 Investigate and explain that sound is produced by vibrating objects and that pitch depends on how fast or slow the object vibrates.
5	Science
	<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.
	Mathematics (B.E.S.T.)
	<u>Number Sense and Operations</u> MA.5.NSO.1.2 Read and write multi-digit numbers with decimals to the thousandths using standard form, word form and expanded form.

Hydroponics 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.
	Mathematics (B.E.S.T.) <u>Data Analysis and Probability</u> MA.K.DP.1.1 Collect and sort objects into categories and compare the categories by counting the objects in each category. Report the results verbally, with a written numeral or with drawings.
1	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.
	Mathematics (B.E.S.T.) <u>Data Analysis and Probability</u> MA.1.DP.1.1 Collect data into categories and represent the results using tally marks or pictographs.
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.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. 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.
	Mathematics (B.E.S.T.) <u>Data Analysis and Probability</u> MA.2.DP.1.1 Collect, categorize and represent data using tally marks, tables, pictographs or bar graphs. Use appropriate titles, labels and units.
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.

Hydroponics System (continued)

3	Mathematics (B.E.S.T.)
	<u>Data Analysis and Probability</u> MA.3.DP.1.1 Collect and represent numerical and categorical data with whole-number values using tables, scaled pictographs, scaled bar graphs or line plots. Use appropriate titles, labels and units.
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.
	Mathematics (B.E.S.T.)
	<u>Data Analysis and Probability</u> MA.4.DP.1.1 Collect and represent numerical data, including fractional values, using tables, stem-and-leaf plots or line plots.
5	Science
	<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.
	Mathematics (B.E.S.T.)
	<u>Data Analysis and Probability</u> MA.5.DP.1.1 Collect and represent numerical data, including fractional and decimal values, using tables, line graphs or line plots.

Board Game Challenge

Mathematics (B.E.S.T.)		
K	<u>Algebraic Reasoning</u>	
	MA.K.AR.1.1	For any number from 1 to 9, find the number that makes 10 when added to the given number.
	MA.K.AR.1.2	Given a number from 0 to 10, find the different ways it can be represented as the sum of two numbers.
	MA.K.AR.1.3	Solve addition and subtraction real-world problems using objects, drawings or equations to represent the problem.
	<u>Geometric Reasoning</u>	
	MA.K.GR.1.1	Identify two- and three-dimensional figures regardless of their size or orientation. Figures are limited to circles, triangles, rectangles, squares, spheres, cubes, cones and cylinders.
	MA.K.GR.1.2	Compare two-dimensional figures based on their similarities, differences and positions. Sort two-dimensional figures based on their similarities and differences. Figures are limited to circles, triangles, rectangles and squares.
1	MA.K.GR.1.3	Compare three-dimensional figures based on their similarities, differences and positions. Sort three-dimensional figures based on their similarities and differences. Figures are limited to spheres, cubes, cones and cylinders.
	MA.K.GR.1.4	Find real-world objects that can be modeled by a given two- or three-dimensional figure. Figures are limited to circles, triangles, rectangles, squares, spheres, cubes, cones and cylinders.
	MA.K.GR.1.5	Combine two-dimensional figures to form a given composite figure. Figures used to form a composite shape are limited to triangles, rectangles and squares.
	<u>Algebraic Reasoning</u>	
	MA.1.AR.1.1	Apply properties of addition to find a sum of three or more whole numbers.
	MA.1.AR.1.2	Solve addition and subtraction real-world problems using objects, drawings or equations to represent the problem.
	MA.1.AR.2.1	Restate a subtraction problem as a missing addend problem using the relationship between addition and subtraction.
2	<u>Geometric Reasoning</u>	
	MA.1.GR.1.1	Identify, compare and sort two- and three-dimensional figures based on their defining attributes. Figures are limited to circles, semi-circles, triangles, rectangles, squares, trapezoids, hexagons, spheres, cubes, rectangular prisms, cones and cylinders.
	MA.1.GR.1.3	Compose and decompose two- and three-dimensional figures. Figures are limited to semi-circles, triangles, rectangles, squares, trapezoids, hexagons, cubes, rectangular prisms, cones and cylinders.
	MA.1.GR.1.4	Given a real-world object, identify parts that are modeled by two- and three-dimensional figures. Figures are limited to semi-circles, triangles, rectangles, squares and hexagons, spheres, cubes, rectangular prisms, cones and cylinders.
	<u>Algebraic Reasoning</u>	
2	MA.2.AR.1.1	Solve one- and two-step addition and subtraction real-world problems.
	MA.2.AR.3.2	Use repeated addition to find the total number of objects in a collection of equal groups. Represent the total number of objects using rectangular arrays and equations.
	<u>Geometric Reasoning</u>	
	MA.2.GR.1.1	Identify and draw two-dimensional figures based on their defining attributes. Figures are limited to triangles, rectangles, squares, pentagons, hexagons and octagons.
	MA.2.GR.1.2	Categorize two-dimensional figures based on the number and length of sides, number of vertices, whether they are closed or not and whether the edges are curved or straight.
2	<u>Measurement</u>	
	MA.2.M.1.3	Solve one- and two-step real-world measurement problems involving addition and subtraction of lengths given in the same units.

Board Game Challenge (continued)

Mathematics (B.E.S.T.)		
3	<u>Data Analysis and Probability</u>	
	MA.3.DP.1.1	Collect and represent numerical and categorical data with whole-number values using tables, scaled pictographs, scaled bar graphs or line plots. Use appropriate titles, labels and units.
	<u>Geometric Reasoning</u>	
	MA.3.GR.1.1	Describe and draw points, lines, line segments, rays, intersecting lines, perpendicular lines and parallel lines. Identify these in two-dimensional figures.
	MA.3.GR.1.2	Identify and draw quadrilaterals based on their defining attributes. Quadrilaterals include parallelograms, rhombi, rectangles, squares and trapezoids.
4	<u>Geometric Reasoning</u>	
	MA.4.GR.1.1	Informally explore angles as an attribute of two-dimensional figures. Identify and classify angles as acute, right, obtuse, straight or reflex.
	MA.4.GR.2.1	Solve perimeter and area mathematical and real-world problems, including problems with unknown sides, for rectangles with whole-number side lengths.
	MA.4.GR.2.2	Solve problems involving rectangles with the same perimeter and different areas or with the same area and different perimeters.
5	<u>Number Sense and Operations</u>	
	MA.5.NSO.1.1	Express how the value of a digit in a multi-digit number with decimals to the thousandths changes if the digit moves one or more places to the left or right.
	MA.5.NSO.1.2	Read and write multi-digit numbers with decimals to the thousandths using standard form, word form and expanded form.
	MA.5.NSO.1.4	Plot, order and compare multi-digit numbers with decimals up to the thousandths.
	MA.5.NSO.1.5	Round multi-digit numbers with decimals to the thousandths to the nearest hundredth, tenth or whole number.
	MA.5.NSO.2.1	Multiply multi-digit whole numbers including using a standard algorithm with procedural fluency.
	MA.5.NSO.2.2	Divide multi-digit whole numbers, up to five digits by two digits, including using a standard algorithm with procedural fluency. Represent remainders as fractions.
	MA.5.NSO.2.3	Add and subtract multi-digit numbers with decimals to the thousandths, including using a standard algorithm with procedural fluency.
	MA.5.NSO.2.4	Explore the multiplication and division of multi-digit numbers with decimals to the hundredths using estimation, rounding and place value.
	MA.5.NSO.2.5	Multiply and divide a multi-digit number with decimals to the tenths by one-tenth and one-hundredth with procedural reliability.