TEACHER'S HANDBOOK

Engineering Science Kit

Exploring Electrical, Software, and Mechanical Engineering

STEM on the Go! Program
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Engineering – Engineering is the ultimate human endeavor, creating solutions to the world's challenges and designing the products that support our quality of life.

Electrical Engineering

Electrical engineers contribute to a wide variety of projects. With an understanding of electricity, electronics, and electromagnetism, they design systems that process information and transmit energy.

Lesson 1 – Light It Up!

Ages 6-11

Light bulbs are such an integral part of everyday life that most people can't imagine being without them. Because most people tend to take light bulbs for granted, they don't think about how they work. In this inquiry-based activity, students will discover how to light a bulb using a simple battery, a piece of wire, and a small light bulb.

Lesson 2 – Conductors & Insulators

Ages 12-14

In this activity, students will discover that conductors are materials that allow electricity to pass through them. They will also learn that insulators are materials through which electricity does not flow – at least not in detectable amounts. They will design and construct a 'circuit tester' to identify conductors and insulators among a group of objects.

Lesson 3 – Wire a House

Ages 15-19

Students have learned how to make an electrical circuit to make a light bulb light up. They will use this knowledge to plan, wire, and light a cardboard box house. Instead of wires, the students will use strips of aluminum foil to carry the electrical circuit from the D-cell to the rooms in their house. To give their house illumination, students will be using recycled Holiday lights in place of bulbs. Their plans will come to life as they problem solve as an electrical engineer!

Software Engineering

Software and computer science engineers develop applications and programs that can accomplish a range of functions. From smartphones, gaming equipment, smart home devices and computer systems, none of these would be possible without software engineers.

Lesson 4 – Video Game Background Design

Ages 6-11

Students will design and build a video game background that will be used to construct an online game. The background is made using a game board with multiple squares and colored blocks to create one large picture that will be captured on a device using the Bloxels Builder app.

Lesson 5 – Video Game Character Design

Ages 12-14

Students will design and build a video game character that will be used in an online video game. The character is made using a game board with multiple squares and colored blocks to create one large picture that will be captured on a device using the Bloxels Builder app. The character can then be used for live video game playing in a game of the player's choice.

Lesson 6 – Video Game Design

Ages 15-19

You don't need to understand fancy code and own super expensive computer programs to make video games anymore. All it takes is a Bloxels Gameboard, some blocks, a mobile device and, of course, your imagination to take the guesswork out of building your own video games! Students will design and create their own video games.

Mechanical Engineering

Mechanical engineers use their knowledge of materials to design and manufacture products and systems that advance the world around us. Mechanical engineers not only design these innovations, they also design the machines that produce and test these innovations.

Lesson 7 – Parking Garages

Ages 6-11

Architects and engineers have similar roles in building designs. Students will experience a bit of both professions by following a set of requirements and meeting given constraints as they create their own model parking garages. Teams experience the engineering design process first-hand as they design, build and test their models. They draw blueprints of their designs, select the construction materials and budget their expenditures. They also test their structures for strength and find their maximum loads.

Lesson 8 – Roller Coasters

Ages 12-14

Students will build their own small-scale model roller coasters using pipe insulation and marbles, and then analyze them like engineers do. They will learn the connection between kinetic and potential energy and frictional effects to design roller coasters that are completely driven by gravity. A class competition will be held using different marbles types to represent different passenger loads determines the most innovative and successful roller coasters.

Lesson 9 – Right on Target: Catapults!

Ages 15-19

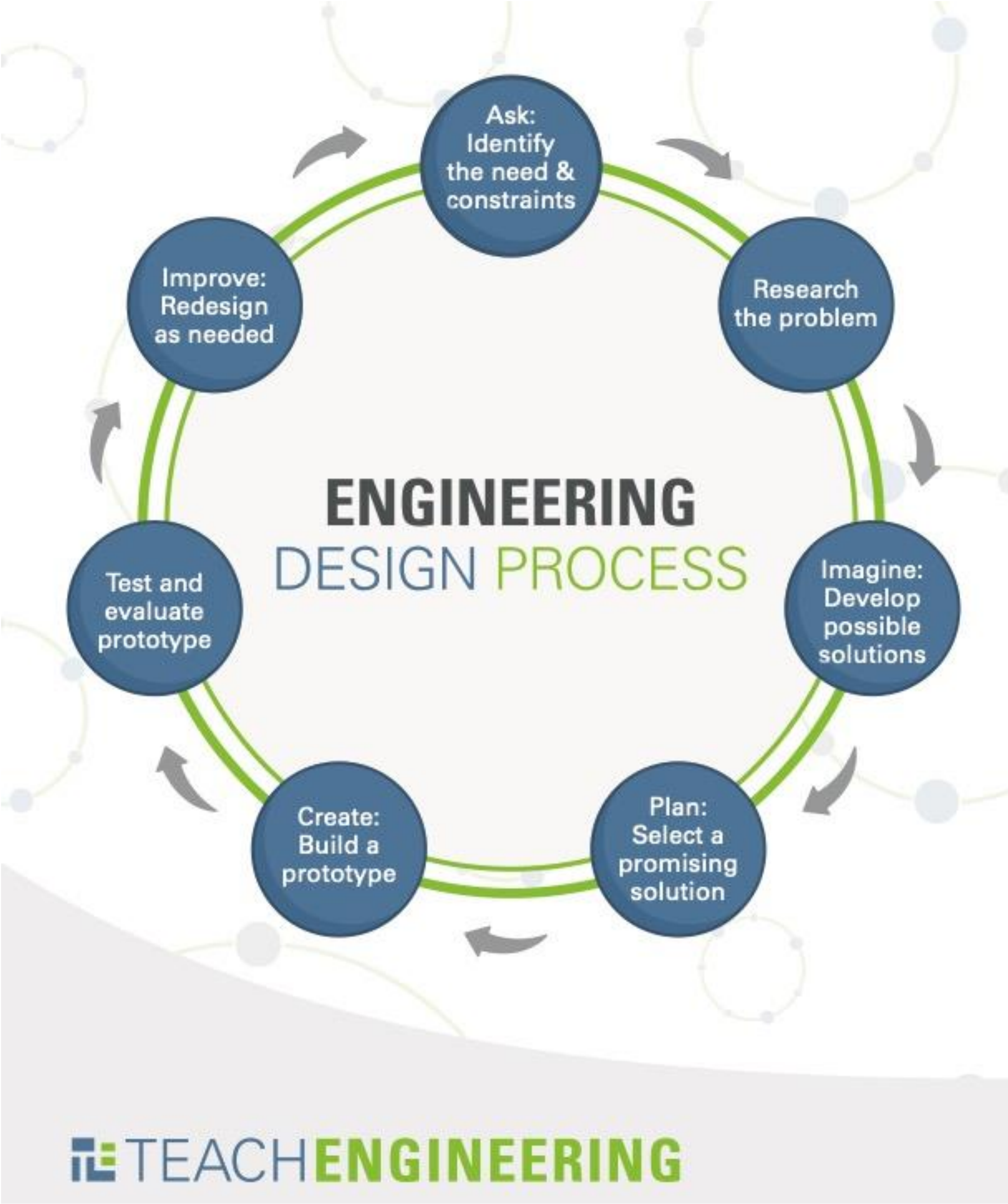
Students experience the engineering design process as they design and build accurate and precise catapults using common materials. They use their catapults to participate in a game in which they launch Ping-Pong balls to attempt to hit various targets.

Earth Science Kit
NGSS Science Standards Addressed

Lesson	1	2	3	4	5	6	7	8	9
NGSS National Science Standards: K-5									
K. Forces & Interactions: Pushes and Pulls							X	X	X
K. Interdependent Relationships in Ecosystems: Animals, Plants, and the Environment									
K. Weather & Climate									
K. Engineering Design	X	X	X	X	X	X	X	X	X
1. Waves: Light & Sound	X	X	X						
1. Structure, Function, and Information									
1. Space Systems: Patterns & Cycles									
2. Structure & Properties of Matter	X	X	X				X	X	X
2. Interdependent Relationships in Ecosystems									
2. Earth's Systems: Processes that Shape the Earth									
K-2. Engineering Design	X	X	X	X	X	X	X	X	X
3. Forces and Interactions							X	X	X
3. Interdependent Relationships in Ecosystems: Environmental Impacts									
3. Inheritance & Variation of Traits: Lifecycles & Traits									
3. Weather & Climate									
4. Energy	X	X	X					X	X
NGSS National Science Standards: K-5									
4. Waves	X	X	X						
4. Structure, Function, & Information Processing									
4. Earth's Systems: Processes that Shape the Earth									
5. Structure and Properties of Matter									
5. Matter and Energy in Organisms and Ecosystems									
5. Earth's Systems									
5. Space Systems: Stars and the Solar System									
3-5. Engineering Design	X	X	X	X	X	X	X	X	X

Lesson	1	2	3	4	5	6	7	8	9
NGSS National Science Standards: Middle School- Physical Science									
MS. Structure & Properties of Matter									
MS. Chemical Reactions									
MS. Forces & Interactions							X	X	X
MS. Energy								X	X
MS. Waves & Electromagnetic Radiation			X	X	X	X			
NGSS National Science Standards: Middle School- Life Science									
MS. Structure, Function, & Information Processing									
MS. Matter & Energy in Organisms & Ecosystems									
MS. Interdependent Relationships in Ecosystems									
MS. Growth, Development, Organism									
NGSS National Science Standards: Middle School- Life Science									
MS. Natural Selection & Adaptations									
NGSS National Science Standards: Middle School- Earth & Space Science									
MS. Space Systems									
MS. History of Earth									
MS. Earth's Systems									
MS. Weather & Climate									
MS. Human Impacts									
NGSS National Science Standards: Middle School- Engineering, Technology, and Applications of Science									
MS. Engineering Design	X	X	X	X	X	X	X	X	X
NGSS National Science Standards: High School- Physical Science									
HS. Structure & Properties of Matter									
HS. Chemical Reactions									
HS. Forces & Interactions							X	X	X
HS. Energy	X	X	X					X	X
HS. Waves & Electromagnetic Radiation									
NGSS National Science Standards: High School- Life Science									
HS. Structure & Function									
HS. Matter & Energy in Organisms & Ecosystems									
HS. Interdependent Relationships in Ecosystems									

Lesson	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
HS. Inheritance & Variation of Traits									
HS. Natural Selection & Evolution									
NGSS National Science Standards: High School- Earth & Space Science									
HS. Space Systems									
HS. History of Earth									
NGSS National Science Standards: High School- Earth & Space Science									
HS. Earth's Systems									
HS. Weather & Climate									
HS. Human Sustainability									
NGSS National Science Standards: High School- Engineering, Technology, and Applications of Science									
HS. Engineering Design	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**



Engineering Design Process

The engineering design process is a series of steps that guides engineering teams as we solve problems. The design process is **iterative**, meaning that we repeat the steps as many times as needed, making improvements along the way as we **learn from failure** and uncover new design possibilities to arrive at great solutions.

Ask: Identify the Need & Constraints

Engineers ask critical questions about what they want to create, whether it be a skyscraper, amusement park ride, bicycle or smartphone. These questions include: What is the problem to solve? What do we want to design? Who is it for? What do we want to accomplish? What are the project requirements? What are the limitations? What is our goal?

Research the Problem

This includes talking to people from many different backgrounds and specialties to assist with researching what products or solutions already exist, or what technologies might be adaptable to your needs.

Imagine: Develop Possible Solutions

You work with a team to brainstorm ideas and develop as many solutions as possible. This is the time to encourage wild ideas and defer judgment! Build on the ideas of others! Stay focused on topic, and have one conversation at a time! Remember: good design is all about teamwork!

Plan: Select a Promising Solution

For many teams this is the hardest step! Revisit the needs, constraints and research from the earlier steps, compare your best ideas, select one solution and make a plan to move forward with it.

Create: Build a Prototype

Building a prototype makes your ideas real! These early versions of the design solution help your team verify whether the design meets the original challenge objectives. Push yourself for creativity, imagination and excellence in design.

Test and Evaluate Prototype

Does it work? Does it solve the need? Communicate the results and get feedback. Analyze and talk about what works, what doesn't and what could be improved.

Improve: Redesign as Needed

Discuss how you could improve your solution. Make revisions. Draw new designs. Fix your design to make your product the best it can be and now, REPEAT!

Electrical Engineering

Lesson 1- Light It Up!
Ages 6-11

Overview
Light bulbs are such an integral part of everyday life that most people can't imagine being without them. Because most people tend to take light bulbs for granted, they don't think about how they work. But light bulbs are an ingenious electrical device. In this inquiry-based activity, students will discover how to light a bulb using a simple battery, a piece of wire, and a small light bulb. Students will be excited that they can get the bulb to light and will be interested in looking for different ways to complete the task.

Learning Objectives
1. Students will discover how to light a bulb using a simple battery, a piece of wire, and a small bulb.
2. Students will discover the effect of an electric current when they complete a closed circuit.

Suggested Timeframe
45-60 minutes

Materials Required (each students needs):
- 1 D-cell battery
- 1 Mini light bulb
- 1 6-inch piece of wire
- 1 Magnifying Glass
- 1 Dry Erase Protective Sleeve for each student
- 1 Thin Expo Marker w/Dry Eraser attached for each student
- 1 "Light It Up" Worksheet
  Students can place their worksheet inside the protective sleeve and use the dry erase marker to do their work.

Assessment
- Activity Embedded Assessment

Introduction/Initiation
"Electricity flows along a path called a circuit. To create a circuit, you need a battery, wire, and whatever else you wish to include in the circuit, such as a bulb. The electricity must be able to move from one end of the battery to the other to create a complete circuit (closed circuit).

How does electricity flow along a circuit? Like many things in nature, electricity is invisible, but we can see and measure the results of the flow. The battery, or energy source, gives electricity its 'push' through a circuit. This push, or voltage, can be thought of as electrical pressure, and is analogous to water pressure. Electrical pressure is measured in volts.

The actual flow of electricity through a circuit is analogous to the flow of water through a hose. The flow of electrical current is measured in amps.

Batteries come in many different shapes and sizes. High-voltage batteries are composed of cells, but the simplest batteries have only one cell. Common one-celled batteries are the AAA, AA, C, and D-cells, all of which can be found in many local stores. Although theses batteries differ in size and in the amount of current they can provide, they all produce approximately 1.5 volts.

The D-cell that students will be working with in this activity has two ends, one marked + (positive) and one marked – (negative). The positive end has a small, raised button on it; the negative end is flat. See figure 1.

Figure 1

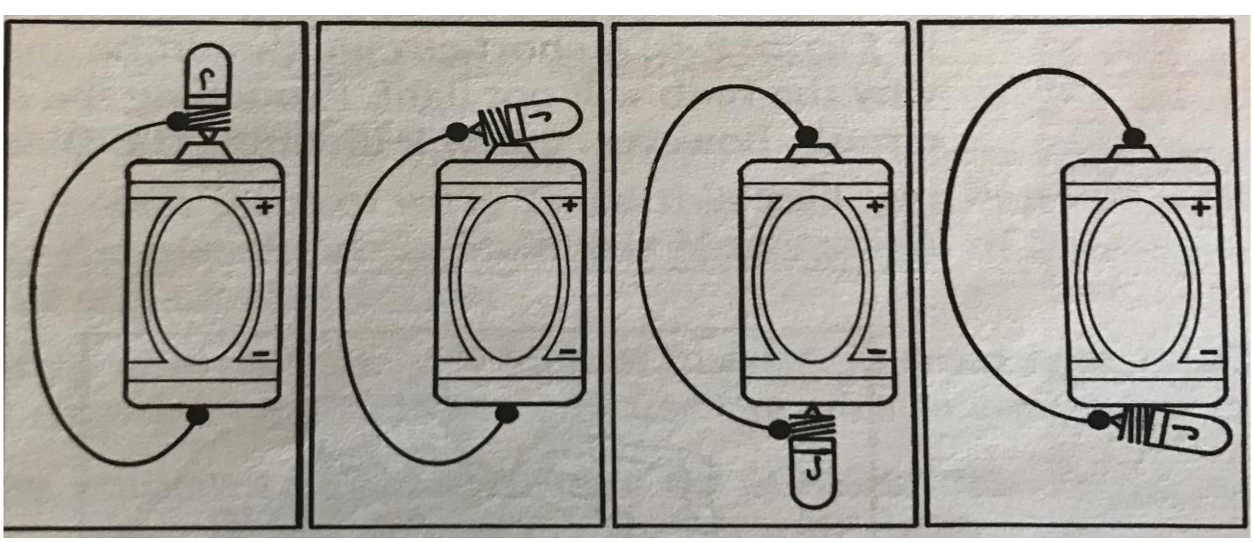
All these components- the battery, the wire, and the bulb- can work together to make a circuit. The circuit is established when there is a continuous path for electricity to travel from one end of the D-cell back to the other end.

Figure 2 shows a student lighting a bulb by using a piece of wire to connect the negative end of the D-cell to the bulb.

Figure 2

There are at least four different ways to light a bulb using one wire, one bulb, and one battery. These ways are illustrated in Figure 3. The bulb lights with the same brightness in each case.

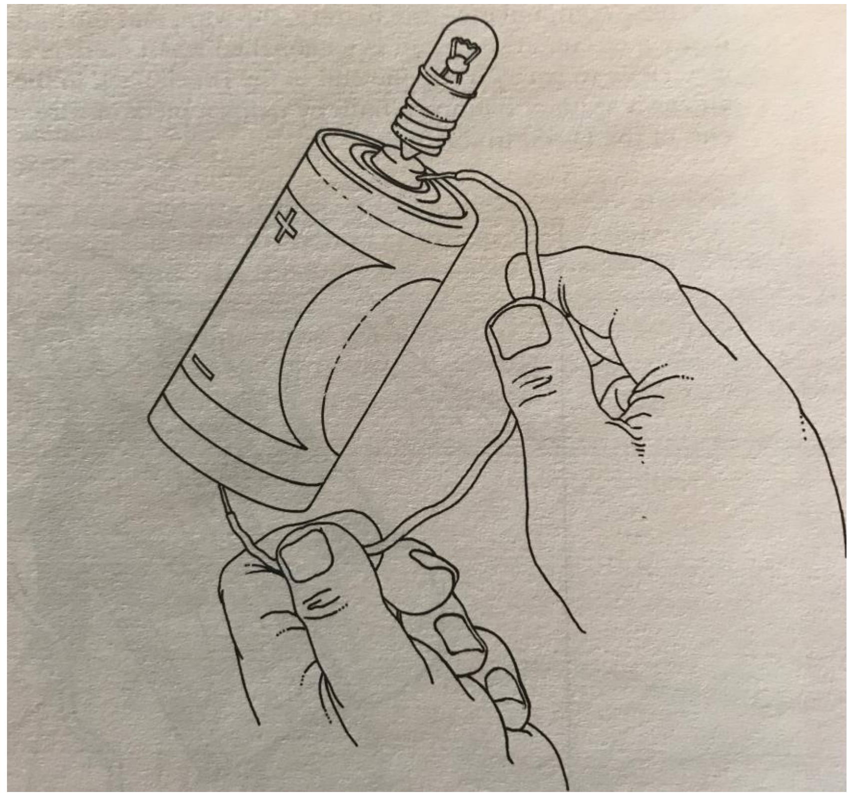
Figure 3



! IMPORTANT INFORMATION !

"Sometimes students may connect a wire directly from one end of the battery to the other without having a bulb in the circuit. When this happens, a short circuit is created, as illustrated in Figure 4. A short circuit provides a conducting pathway from one end of the battery to the other, but bypasses the bulb."

Figure 4



"Short circuits in a house or in an automobile can produce dramatic sparks and enough heat to melt metals and start a fire. Short circuits with D-cells are not dangerous, but they do drain the electrical energy from the batteries. If left connected for several minutes, both the wire and D-call will get warm."

REMIND STUDENTS OF ELECTRICAL SAFETY! DO NOT STICK ANYTHING INTO ELECTRICAL OUTLETS OR POWER SOURCES! YOU CAN GET SERIOUSLY HURT!

Procedure

Before the Activity

1. Gather all supplies.
2. Get 1 "Light It Up!" Worksheet, 1 Protective Sleeve, 1 Thin Expo Marker/Eraser for each student.

With the Students:

1. Tell the students that today they will participate in a 'STEM CHALLENGE!' Their challenge is to use the materials provided to light the bulb.
2. Have each student look at their "Light it Up!" Worksheet. Give each student a light bulb and a magnifying glass. Have students draw a detailed picture of a light bulb using the magnifying glass to help see inside the bulb.
3. As students finish their drawing, check to make sure they have drawn what they see on the inside (such as the filament, etc).
4. Once finished, give each student a wire, a bulb, and a D-cell. Using only these materials, ask each student to make the bulb light. As students work at this task, reassure them that it can be done. If they need coaching, ask: "How could you connect together the wires, the D-cell, and the bulb to get the bulb to light?"
5. The first student who succeeds in lighting the bulb usually lets out an excited yell! That initial excitement encourages other students to quickly solve the problem.
6. Circulate around the classroom as students work. Some students will "short circuit" the D-cell by connecting the wire from one end of the D-cell to the other, without having the electricity go through the bulb.
7. Have students draw the ways on their "Light It Up!" Worksheet.

8. About 10 minutes before the end of the class, have students clean up and put their materials away. This will leave time for a final discussion with the class. Have them share the ways they discovered to light the bulb.

Assessment

Activity Embedded Assessment

Worksheet: Have the students record their observations and solutions on their "Light It Up!" Worksheet. After students have finished their worksheet, have them share their results with the class.

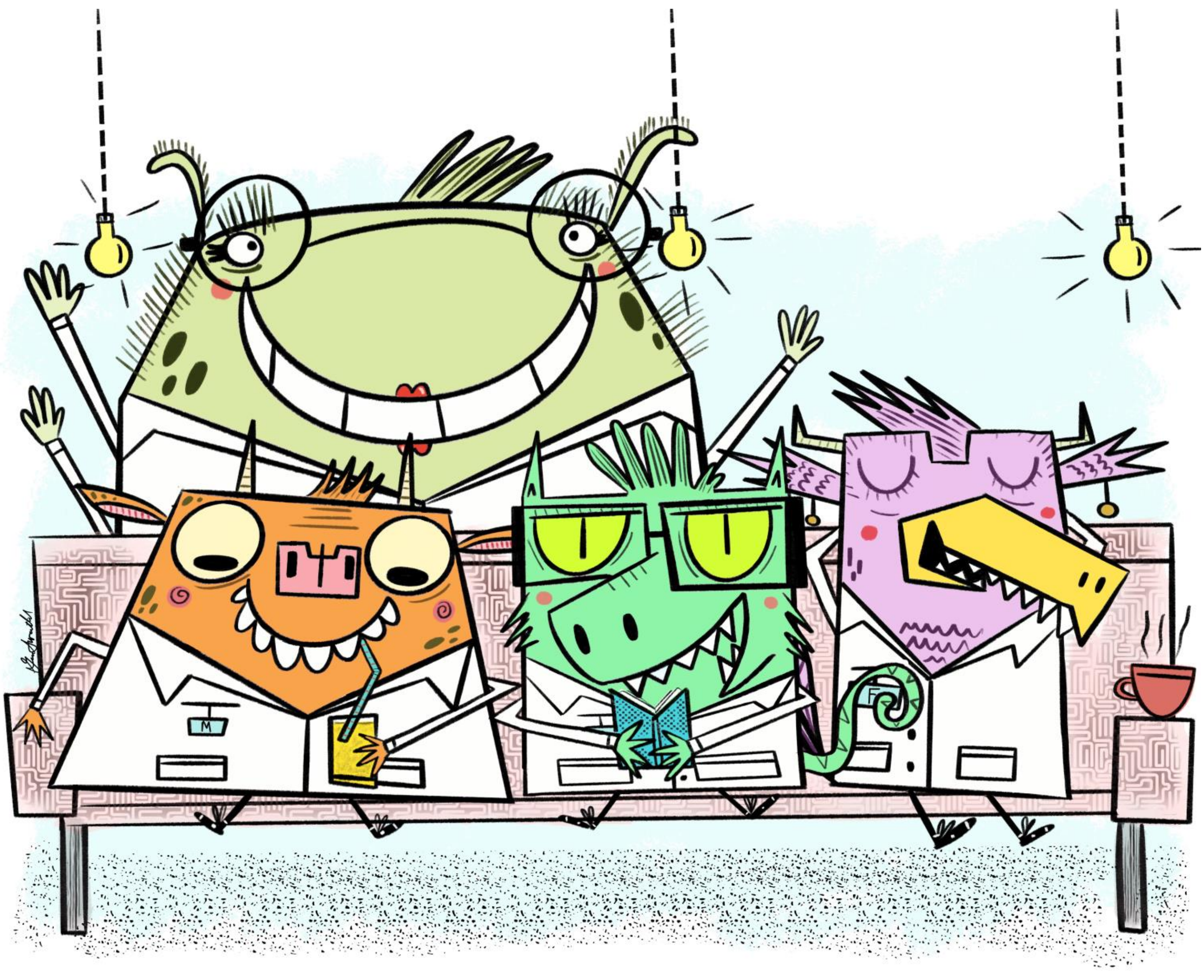
Activity Extensions

- Expect students to be curious following this lesson. Students can check out how batteries work by watching a video on YouTube from Mystery Doug's Channel called, "How Do Batteries Work?" https://www.youtube.com/watch?v=uviF7ensN1I 6 minutes 2 seconds

Activity Scaling

For lower grades or younger students, give them some hints during their investigative process without giving them the answer. This lesson is meant to take time, keep encouraging them!

For higher grades, you can challenge the students **after** they've figured out the four ways by asking them how they would get the bulb to be brighter? Ask them what materials they would need from you to make it happen? Give them what they need and let them investigate to see if they can solve the problem.



Name ____________________________ Date _________________________

Lesson 1: "Light It Up!"

<u>1. Imagine:</u> What does your light bulb look like? Use your magnifying glass to get a closer look.

Draw a few pictures of your light bulb in the box below- What does it look like on the inside?

<u>2. Plan</u>: Select a solution. Predict how you think you will connect the bulb, wire, and D-cell to make the bulb light up. Draw a picture of your idea for a solution below.

Prediction

<u>3. Create & Build</u>: Use the bulb, wire, and D-cell to construct a circuit. How many different ways can you get the light bulb to light up?

<u>4. Test & Evaluate</u>: Did you get the bulb to light up? If you were able to get the bulb to light up, draw a picture of your circuit in the box below. There are at least 4 possible solutions.

Result #1	Result #2	Result #3	Result #4

Electrical Engineering

Lesson 2- Conductors and Insulators
Ages 12-14

Overview
Conductors and insulators are important components in electric circuits. Conductors are materials through which electricity can travel. Insulators, on the other hand, are materials through which electricity cannot travel.

To determine if a material is a conductor or an insulator, students will be asked to place the material between the two wires of the circuit tester. Figure 1 shows how to use a circuit tester to see if an object can be part of a circuit. If the bulb lights, then students will know that the material conducts electricity.

Learning Objectives
1. Students will develop an understanding of the behavior of electrical conductors.
2. Students will learn how to use a circuit tester to identify conductors and insulators.

Suggested Timeframe
45-60 minutes

Materials Required (each students needs):
- 1 D-cell battery
- 1 D-cell battery holder
- 1 Mini light bulb
- 3, 6-inch pieces of wire
- 1 light bulb holder
- 1 Dry Erase Protective Sleeve for each student
- 1 Thin Expo Marker w/Dry Eraser attached for each student
- 1 “Conductors and Insulators” Worksheet
  Students can place their worksheet inside the protective sleeve and use the dry erase marker to do their work.

Assessment
- Activity Embedded Assessment

Introduction/Initiation
“Conductors and insulators are important components in electric circuits. Conductors are materials through which electricity can travel. Insulators, on the other hand, are materials through which electricity cannot travel. To determine if a material is a conductor or an insulator, students will be asked to place the material between the two wires of the circuit tester.

You will use your circuit tester to test different objects around you such as (pen, pencil, your shoes, the paper, the dry erase marker, etc. Remember ***do not test items near or containing water as well as:***

DO NOT STICK ANYTHING
INTO ELECTRICAL OUTLETS OR POWER SOURCES!
YOU CAN GET SERIOUSLY HURT!

There are some materials that are called semiconductor meaning that they sometimes act like a conductor and at other times act like an insulator. For the sake of the unit, classify as either a conductor or insulator."

Procedure

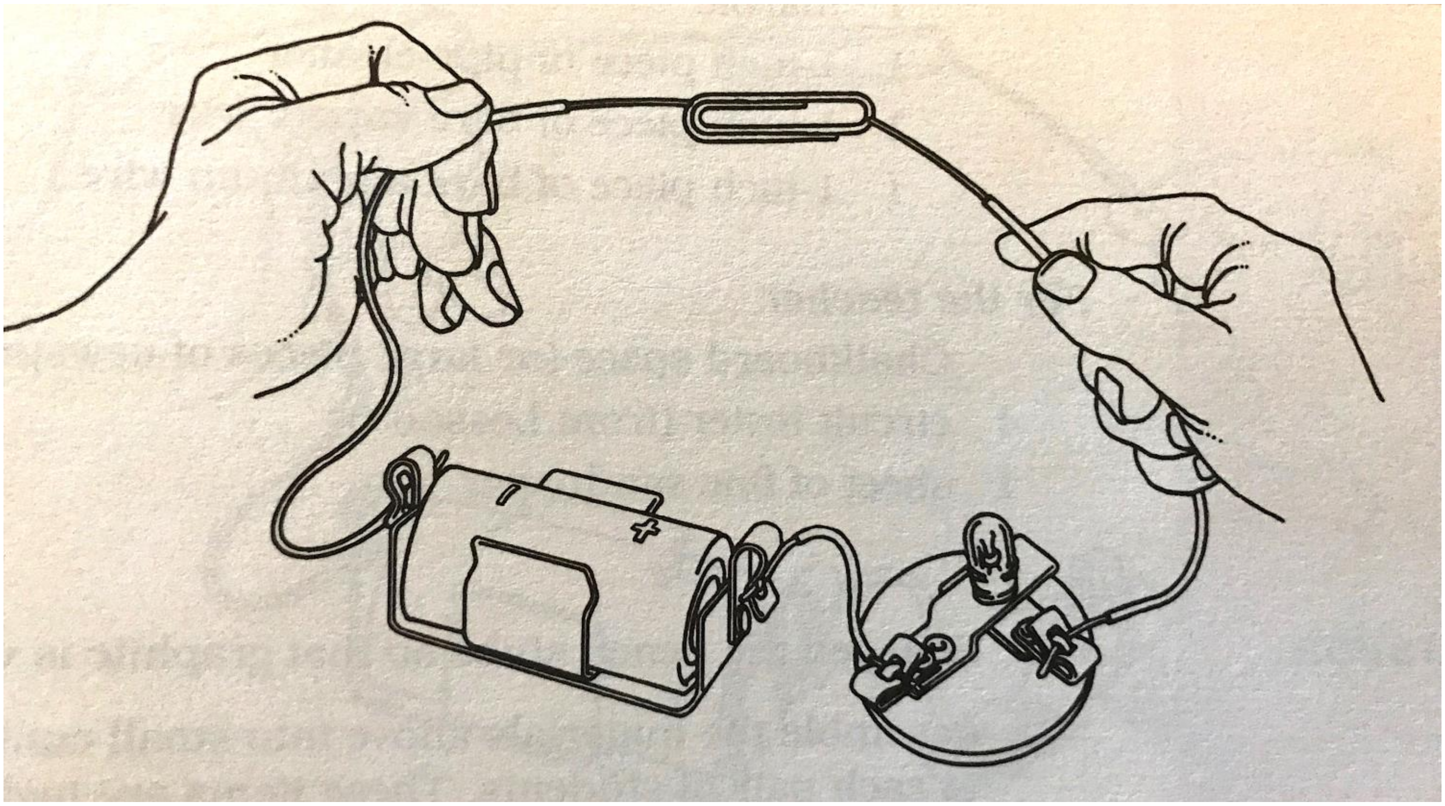
Before the Activity

1. Gather all supplies.
2. Get 1 "Conductor and Insulator" Worksheet, 1 Protective Sleeve, 1 Thin Expo Marker/Eraser for each student.

With the Students:

1. Have each student build a circuit tester device as shown in Figure 1.

Figure 1 – Using a circuit tester



2. Ask the students how to use the circuit tester device to see if an object, such as the paperclip shown, can be part of the circuit. Ask them, "What does it mean if the bulb lights when you touch the wires to the ends of the paperclip or object?"

   Help students understand that if the bulb lights, it means the electricity had to travel through the paperclip or object. Have them use their circuit tester on an object that does not conduct, such as a pen cap, and discuss why the bulb does not light.
3. Have each student choose materials around the room to test with their circuit tester. Some examples include: chair, pencil, paperclip, pen, pen cap, a book, carpet, tile floor, etc. **Remind the students not to test objects with water or that are electrical.**
4. Have students write the name of their object tested on their Conductor & Insulator sheet, and predict whether they think the light will be on or off when the item is included in the circuit.
5. Have each student use their circuit tester to test their own set of assorted materials. Encourage the students to test materials they find in the room with them.

6. About 5 minutes before the end of the class, have students return their items and materials and share results with the class.

Assessment

Activity Embedded Assessment

Worksheet: Have the students record their observations and solutions on their “Insulator & Conductor” Worksheet. After students have finished their worksheet, have them share their results with the class.

Activity Extensions

- Tell students you want them to think about the ways electricity is used and transmitted to their homes. What parts of the system are insulators? Conductors? For example, what about power lines, power poles, or the glass knobs used to support the wires? Have students conduct research about how electricity gets into their homes.

Activity Scaling

For lower grades or younger students, have them complete this activity with a partner and provide the materials for them to test ahead of time. Maybe put random items you can find on the table for them to test without them walking around the room to find test items.

For higher grades, you can challenge the students **by not** showing them the picture of the circuit tester and having them design and build their own ‘tester’. Provide them with all necessary materials and explain that their tester should be able to tell if electricity travels through the object or not.

Name ____________________________ Date _________________________

Lesson 2: "Conductors & Insulators"

1. Imagine: What does your circuit tester look like? Use your magnifying glass to get a closer look.

Draw your conductors and insulators circuit tester in the box below- What does it look like?

2. Plan: Draw a picture or use words to explain how your circuit tester will tell you if your object is a conductor or an insulator.

Prediction

3. Create & Build: Use the bulb, bulb holder, wires, D-cell and D-cell holder to construct a circuit tester. How many different objects can you test?

4. Test & Evaluate: Use the list to predict whether you think the light will be on or off when the item is included in your circuit.

Item	Predictions		Experiment Result
	Light On?	Light Off?	

Electrical Engineering

Lesson 3- Wire a House

Ages 15-19

Overview

Students will plan to wire and light a cardboard box house. There is some similarity between the wiring students did in Lesson 1 and 2 to get the light bulb to light up. In this activity, students will have a chance to apply what they have learned in those lessons by drawing up a plan for wiring an cardboard box 'house' and then implement their plan.

Learning Objectives

1. Students will work in teams to use knowledge gained during the first two lessons to draw up plans for wiring a house.
2. Students will consider different strategies for making an effective writing scheme.

Suggested Timeframe

45-60 minutes

Materials Required (each team of 2 students needs):

- D-cell battery
- 1 Cardboard Box
- 2-3 Mini light bulbs (Use Holiday Lights)
- 1 Piece of Aluminum Foil (To be cut into strips)
- 1 Glue Stick
- 1 Pair of Scissors
- 1 Pair of Wire Strippers to cut lights and strip ends
- 1 Dry Erase Protective Sleeve for each student
- 1 Thin Expo Marker w/Dry Eraser attached for each student
- 1 "Wire a House" Worksheet
  Students can place their worksheet inside the protective sleeve and use the dry erase marker to do their work.

Assessment

- Activity Embedded Assessment

Introduction/Initiation

"Today, you're going to use your knowledge of how to make a light bulb light up in a circuit and try to build a house out of a cardboard box and get the rooms to light up. You will start by making a plan first and drawing your ideas of how you're going to get the electricity to travel from room to room once the electricity has left the D-cell.

You will not be using wires today to transfer the electricity and instead you will be using strips of aluminum foil to carry the energy from the D-Cell to the light bulbs in each room. The light bulbs will be recycled Holiday lights that have been cut off the long strand.

There is some similarity between making a circuit with the wires, D-cell, and bulb and the wiring done in a cardboard box house. For example, you will need to grapple with the way the foil wires go from the power source (battery outside the box), over the walls and into each room, just as electricians do.

You may have other issues to think about as you work on this project. For example, should you use only one D-cell and one light for all of the rooms, which would keep the wiring quite simple and self-

contained within each of the rooms? Or, should you use two D-cells as a power source, and have them placed "outside" the house, similar to the way power is send from the electric company to "real" houses?

Start by drawing your plan, showing in your blueprint how many rooms and lights you will need for your project. Some essential questions to think about that are important:

- *How many rooms will your house have?*
- *Where will the lights be placed in your plans?*
- *Where will the D-cell battery/batteries be placed?*
- *Where will the aluminum foil wires be placed?*

After your drawing is complete, you can start designing and constructing your cardboard box house.

Procedure

Before the Activity

1. Gather all supplies.
2. Get 1 "Wire a House" Worksheet, 1 Protective Sleeve, 1 Thin Expo Marker/Eraser for each student.

With the Students:

PART 1- DRAWING THE BLUEPRINTS

1. Tell students they will be wiring a box as though it were a house. Organize them in teams of two. Have each team choose one person to be the discussion leader and another to do the drawing. Have each team work together to draw a plan for their house wiring.
2. Speaking to the class as a whole, remind the students of the work they have already done designing circuits, looking at the differences between getting the light bulb to light up lesson and the conductor/insulator lesson.
3. Tell students that their task is to organize their house so that there is a light in each room.
4. Have students go to work. Circulate around the room, watching and serving as a resource person where needed. By the end of ten minutes, each group should have some version of a plan for wiring they will do next.

PART 2- WIRING THE HOUSE

1. Remind students of the excellent plans they have created or have available for their use. Tell them how you will handle any needs for more foil or other materials. Urge them to keep working together and to talk to members of their group as they work so that each member has an opportunity to contribute.
2. Point out that the foil wires need to always be in contact with each other since they are using pieces to construct a long strip.
3. When students have finished wiring and lighting, have them share with each other and then clean up.

Assessment

Activity Embedded Assessment

Worksheet: Have the students record their observations and solutions on their "Wire a House" Worksheet. After students have finished their worksheet, have them share their results with the class.

Activity Extensions

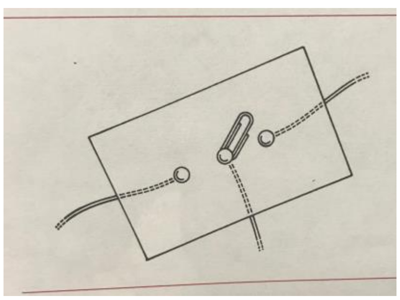
- Have each student group present their house to the class with an oral presentation and a demonstration. Or, have each group prepare a written description of their house. The written description could recount, among other things the work they did in making their plans, what issues and problems they had to solve in their group, any changes they made as they did the wiring, any problems that arose, and how they were resolved.

Activity Scaling

For lower grades or younger students, put them in a larger group to design and build the house. Or, have them make a house with just one room as opposed to more rooms, which will make wiring easier.

For higher grades, you can challenge the students **after** they've wired their house. Have the students consider creating and using a switch in one of the rooms. Have them come up with a plan to be able to turn the lights on and off in a single room. Below is a picture of an example of a switch. This is just to be used as a reference as there are many possible ideas that students will come up with to turn the light on and off in a room.

The paperclip acts as a switch between the two brass fasteners. The brass fasteners are connected to wires, which is connected to the light bulb and D-cell. When the paperclip is in the air as seen as the picture, the circuit is open and the light bulb will not light up.



Name ____________________________ Date _________________________

Lesson 3: "Wire a House"

1. Imagine: What does your cardboard house look like?

Draw your plan for your house in the box below- How many rooms will your house have? Where will the lights be placed in your plans? Where will the D-cell be placed? Where will you place the foil wires? Draw a birds eye view of your house (top looking down)

2. Plan: Draw a picture or use words to explain how many D-cells you will use and how you will connect the foil and lights to make a circuit.

Prediction

3. Create & Build: Use the bulbs, foil wires, and D-cell(s) to construct a circuit and make your house light up. How many rooms will you get to illuminate?

4. Test & Evaluate: Use the list to predict whether you think the light will be on or off when the item is included in your circuit.

Present your house to the class and demonstrate how it works. Share the following information:

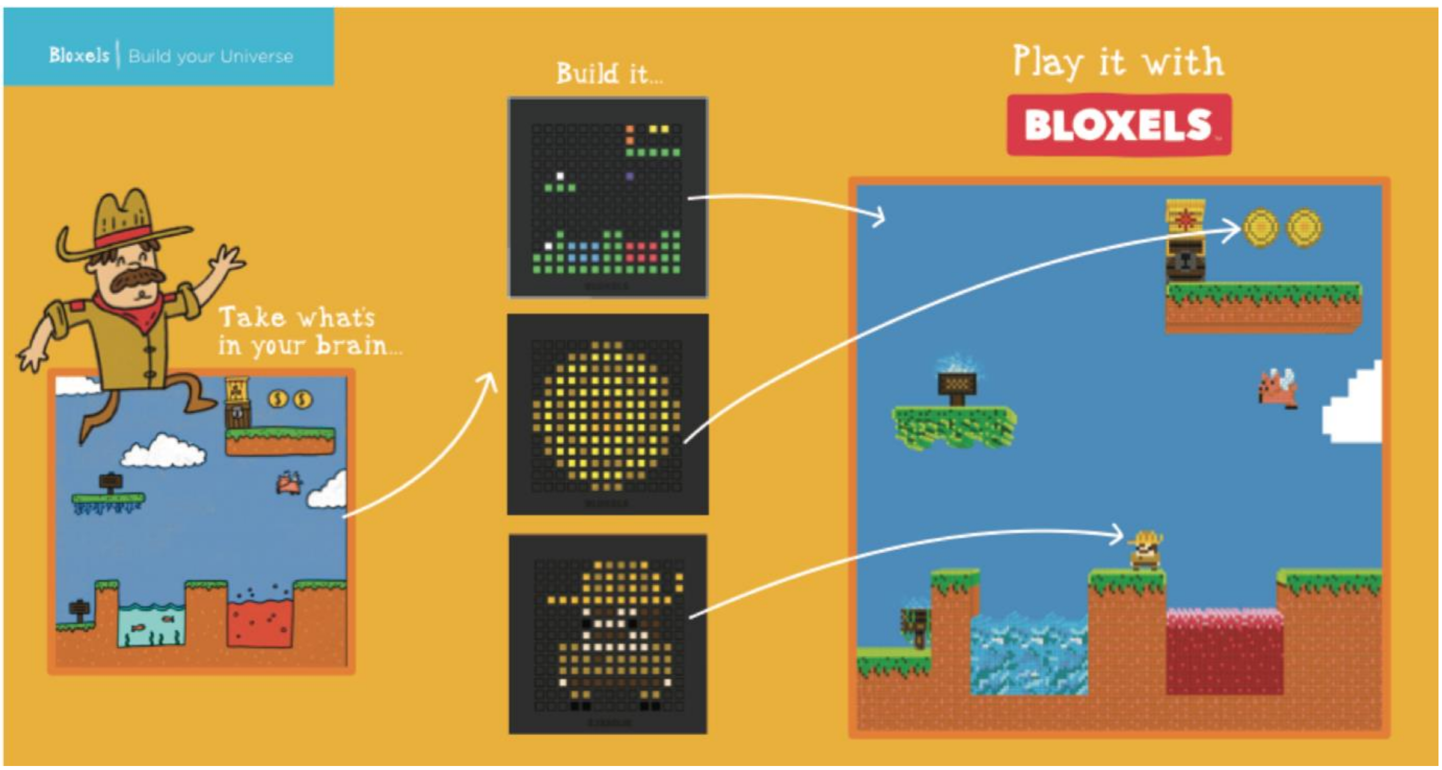
- What issues and problems did you have to solve in your group?
- What changes did you make as you did the wiring?
- What strategies did you use to light up the rooms in your house?
- How did you get the circuit to go from one room to another?

Software Engineering

Lesson 4- Video Game Background Design with Bloxels
Ages 6-11

Overview
Bloxels is a hands-on platform for kids to build, collaborate, and tell stories through video game creation. Students can use colored blocks to design their characters and settings on a gameboard to tell their own amazing stories! The game board is scanned using the free iPad app to make the creation come to life!

Step 1: Unpack the Gameboard(s)
The 13x13 Gameboard provides the canvas for your students, a sandbox where their imaginations will unfold. Students will arrange the blocks within the boundaries of the board in order to create Characters & decorations (using the blocks as art) and Layouts (where the blocks have specific meanings).



Step 2: Watch the Tutorial Videos
Bloxels has simplified the game build process to enable students to build games in minutes, where most game building software can take many hours if not days to have a playable game.

However, Bloxels still requires some practice to familiarize yourself with the creation interface – remember, this is a software development tool, not a game! Unless you want to figure it all out on your own, now is the time to watch our tutorial videos to familiarize yourself with the Bloxels Builder App, and don't be afraid to watch them with your students as well.

Watch all of the videos here to familiarize yourself with the game editor.

- Just Getting Started Tutorial: https://vimeo.com/322105023
- Building Boards: https://www.youtube.com/watch?v=rZg9HJWHBgk

Learning Objectives

1. Students will follow the design thinking process and create a video game background.
2. Students will design and build a background in the Bloxels Builder app to be used later for a video game.

Suggested Timeframe

45-60 minutes

Materials Required (each group of students need):

- 1 Device (iPad) with Bloxels Builder app installed
- Bloxels Gameboard: (one per group)
- Bloxels Blocks

Assessment

- Activity Embedded Assessment

Introduction/Initiation

*"*Tell students that today they are going to design the background to a video game! They will have a few minutes to play a few video games to get ideas for designing their own background. The game background sets the overall theme for your world. It consists of 169 squares on a 13x13 board stitched together to create one large image. The background of the video game can be as simple as a single color or as complex as a mountain range."

Have students work in groups to explore different video games in the Bloxels app. Give each group an iPad.

1. Instruct students to open the Bloxels app and go to the Infinity Wall.
2. Have students choose **three** games to play. Give students 4 minutes to play and evaluate the background/theme of each game, for a **total of 12 minutes**.

After, discuss with students what types of backgrounds they observed while playing the games. Was there a theme that they liked a lot?

Give each group a few min. to brainstorm a background that they will create using the Bloxel app and board.

Procedure

Before the Activity

1. Gather all supplies.
2. Get 1 Bloxels Game Board, a set of Bloxel Blockes, and 1 Device (iPad).

With the Students:

1. https://youtu.be/FpAN9t2GWbg- Video Tutorial for creating a character

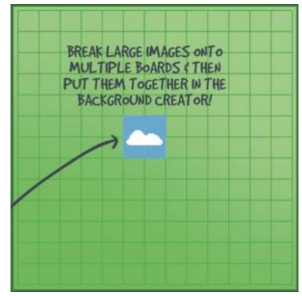
2. For students build their background have them follow the steps below:

   Step 1- Tap the **BUILDER** button on the Home Screen.

   Step 2- Tap the **BACKGROUNDS** button on the Builder Screen. *In the Background Builder you can view all the backgrounds you've created in your Library.*

Step 3- Tap the green + button to **CREATE NEW BACKGROUND** or tap on an existing background to **OPEN**.

Step 4- Once you tap the green + button, you'll see a grid board like this:



Step 5- Students can either use the snap tool to put colored squares into the grid OR they can use the draw tool to draw images onto a blank canvas.

Step 6- When students are done, have them go to the top of the screen and name their background.

Step 7- After naming their background, have students tap on the green mountain symbol on the top right of the screen.

Step 8- Tap the **SHARE** button to share the background with the class library, and then click **YES** to confirm.

3. About 5 minutes before the end of the class, have students return their items and materials and share results with the class.

Assessment

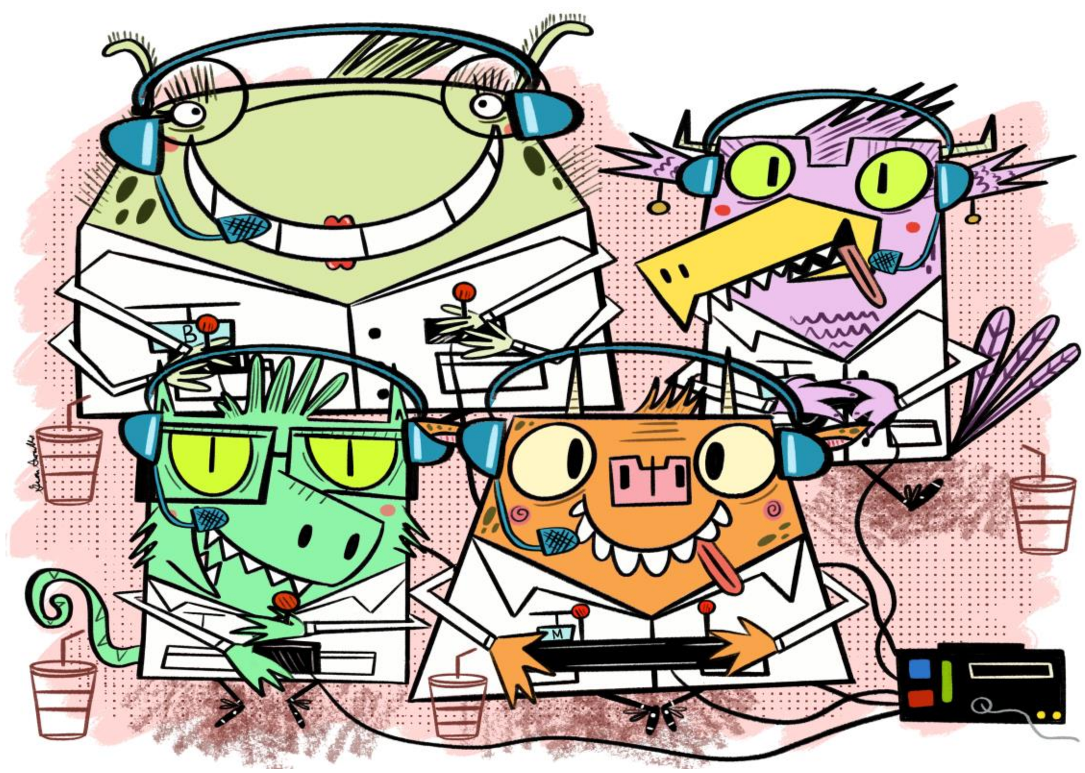
Activity Embedded Assessment

Worksheet: Have the students record their background designs on the "Background Design" Worksheet. After students have finished their worksheet, have them use their designs in the Bloxels app.

Activity Scaling

For lower grades or younger students, have them design their background using the 'snap' feature which will allow them to simply plug in colors to design.

For higher grades, you can challenge them to create their background using the 'draw' feature which gives them more options using the toolbar.



Name ____________________________ Date _________________________

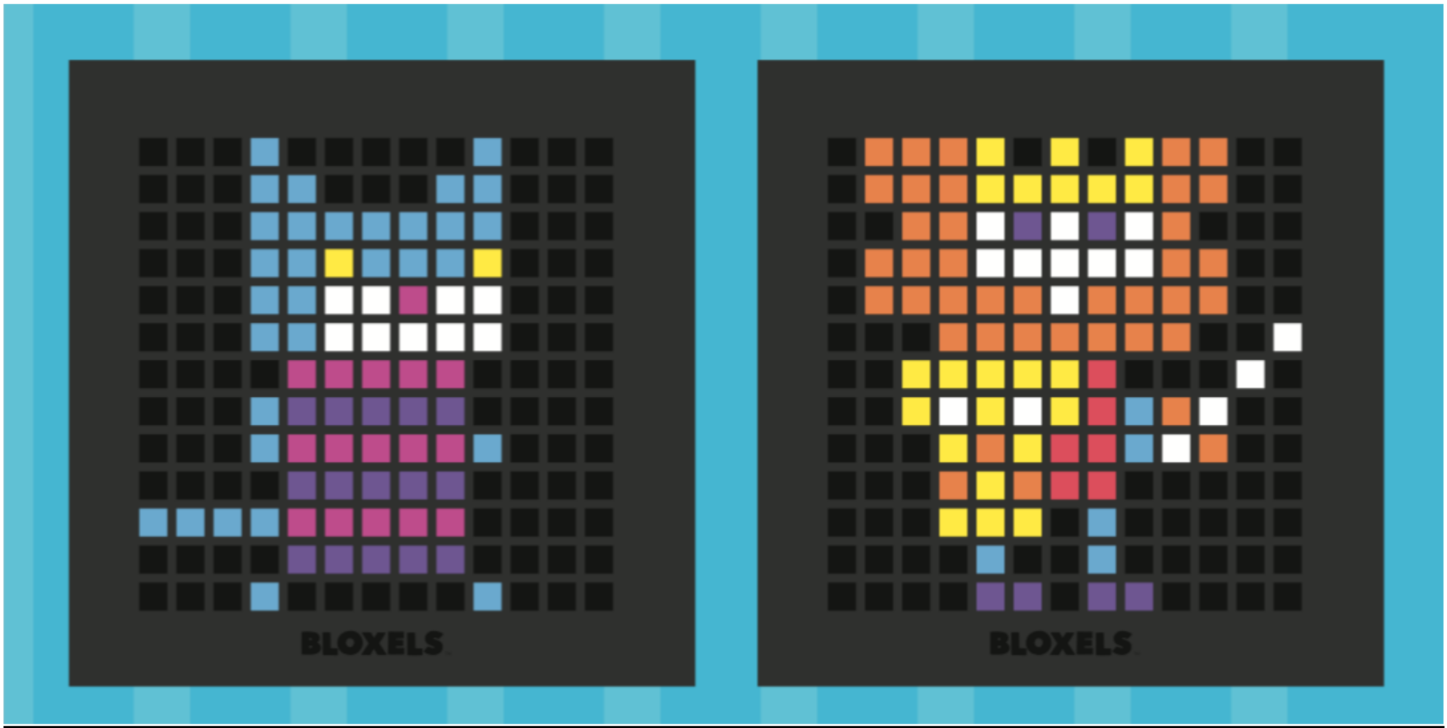
Lesson 4: “Background Design”

1. Imagine: What does your video game look like? What theme are you and your group interested in? Write down a few ideas for your video game.

2. Plan: Select a solution. Use the grid below and using crayons color the squares to show what your background would look like on the Bloxel game board. You will use your drawing as a guide to build your background.

Lesson 5- Video Game Character Design with Bloxels
Ages 12-14

Overview
Bloxels is a hands-on platform for kids to build, collaborate, and tell stories through video game creation. Students can use colored blocks to design their characters and settings on a gameboard to tell their own amazing stories! The game board is scanned using the free iPad app to make the creation come to life!



Step 1: Unpack the Gameboard(s)
The 13x13 Gameboard provides the canvas for your students, a sandbox where their imaginations will unfold. Students will arrange the blocks within the boundaries of the board in order to create Characters & decorations (using the blocks as art) and Layouts (where the blocks have specific meanings).

Step 2: Install the FREE Bloxels Builder App
Visit the app store on your tablet or device and search "Bloxels" to download the latest version of Bloxels, or click here to for links and information on device support.

Step 3: QuickPlay & Familiarization
Want to dive in and see how the game plays? Hit **Quick Play** on the homepage page for the app. Pick a Character, Layout, and Decoration, and just play! You'll get a feel for the controls, and if you look close will start to understand how layouts and artwork combine to make a game from the 13x13 gameboards grid.

On this screen you can also test capturing game layouts (using the color guide on the previous page), or a game character (where the colors are used simply as art).

Step 4: Watch the Tutorial Videos
Bloxels has simplified the game build process to enable students to build games in minutes, where most game building software can take many hours if not days to have a playable game.

However, Bloxels still requires some practice to familiarize yourself with the creation interface – remember, this is a software development tool, not a game! Unless you want to figure it all out on your own, now is the time to watch our tutorial videos to familiarize yourself with the Bloxels Builder App, and don't be afraid to watch them with your students as well.

Watch all of the videos here to familiarize yourself with the game editor.

- Just Getting Started Tutorial: https://vimeo.com/322105023
- Building Characters: https://www.youtube.com/watch?v=hBGpBiS-QKU

Learning Objectives
1. Students will follow the engineering design process while designing their character.
2. Students will design and build a character in Bloxels Builder app.

Suggested Timeframe
60 minutes

Materials Required (each group of students need):
- 1 Device (iPad) with Bloxels Builder app installed
- Bloxels Gameboard: (one per group)
- Bloxels Blocks
- 1 Dry Erase Protective Sleeve for each student
- 1 Thin Expo Marker w/Dry Eraser attached for each student
- 1 "Character Design" Worksheet
  Students can place their worksheet inside the protective sleeve and use the dry erase marker to do their work.

Assessment
- Activity Embedded Assessment (Character Design Sheet)

Introduction/Initiation
"Have the following questions displayed on the classroom board to answer OR ask the students prior to the activity.

1. What is your favorite game to play?
2. Why is this game your favorite?
3. What characteristics make this game fun?

Quickly (in **2 minutes**) discuss student responses to the questions. Emphasize that there are multiple characteristics that make a game "fun." (i.e. challenging, funny, etc.)

Procedure
Before the Activity
3. Gather all supplies.
4. Get 1 "Character Design" Worksheet, 1 Protective Sleeve, 1 Thin Expo Marker/Eraser for each Group, 1 Bloxels Game Board, Bloxels Blockes, and 1 Device.

With the Students:

Part 1- Research the Problem: Speed Design Challenge

1. Have each group complete the Speed Design Challenge. This will give students the background knowledge to understand what attributes make a great video game character and which do not.
2. Instruct students to open the Bloxels app and go to the Infinity Wall.
3. Have students choose **three** games to play. Give students 4 minutes to play and evaluate the pros & cons of each game, for a **total of 12 minutes**.

Roam around the classroom and give feedback on the pros/cons students have noted. Here are some examples of student responses:

PRO: "The enemies in this game made it really intense and exciting!"

CON: "There were too many hazards. It was too difficult for my character to navigate the game, and practice didn't make it easier, just more frustrating"

Part 2- Imagine a Solution & Plan

1. Give students **3 minutes** to reflect on the observations during the research step and think of what type of character they would want. Roam around the classroom and give feedback that pushes students to be specific with the challenges they define.

Examples of student responses:

"Based on my play testing I need a character that is easy to move around. They should have an outfit that would help protect them, like a hat to protect their head."

Part 3- Create a Character

1. https://youtu.be/dBI7vJ3CSSA - Video Tutorial for creating a character

   Use the Gameboard and Blocks to build your first character. In the Bloxels EDU app, capture and edit your characters colors and animation states, and share with your class in the Class Library.

2. To have students build their characters have them follow the steps below:

   Step 1- Tap the **BUILDER** button on the Home Screen.

   Step 2- Tap the **CHARACTERS** button on the Builder Screen. *In the Character Builder you can view all the characters you've created in your Library.*

   Step 3- Tap the **CREATE NEW CHARACTER** button to create a new character or tap on an existing character to **OPEN**.

   Step 4- In the Character Builder you can Capture a character from the Bloxels Gameboard, edit the colors using the Color Wheel, and animate its Idle, Walk, and Jump states.

   Step 5-In your characters **IDLE** state, tap the **+** button on the right of your frame to create a second frame.

Step 6- In the second frame, use the Undo, Redo, Erase, Copy, and Paste buttons, transformation arrows, and the Color Wheel to edit and animate your character. Maybe its eyes are blinking, or its shrugging its shoulders. *You can add as many animation frames as you'd like in each of your characters states.*

Use the slider on the bottom left of the screen to adjust your animations speed. To slow your animation down, slide it to the left, to speed your animation up, slide it to the right.

You can view your characters animation to the left of his Idle state.

Step 7- Tap back on your characters first frame, then tap the **COPY** button, to copy your character to your clipboard.

Step 8- Tap the **WALK** state.

Step 9- Tap the **PASTE** button.

Step 10- Use the Undo, Redo, Erase, Copy, and Paste buttons, transformation arrows, and the Color Wheel to edit and animate your character to look like it's walking.

*You can tap the green **PLAY** button at any time to test out your characters animation states. Tap the blue **EDIT** button to get back to the Character Builder.*

Step 11- Tap the **COPY** button, to copy your characters frame to your clipboard.

Step 12- Tap the **JUMP** state.

Step 13- Tap the **PASTE** button.

Step 14- Use the Undo, Redo, Erase, Copy, and Paste buttons, transformation arrows, and the Color Wheel to edit and animate your character to look like it's jumping or flying.
Step 15- Don't forget to give your character a name! Tap the **COGWHEEL** to open up the keyboard and type in your characters name.

Step 16- Tap the **CHARACTER** icon in the top navigation menu to return to your Character Library.

Step 17- Tap the **OPEN LAST EDITED** button for quick access to your most recently edited character.

Step 18- Tap on a character to **OPEN** the Character Builder, **SHARE** with your Class Library, or **DELETE** from your Character Library.

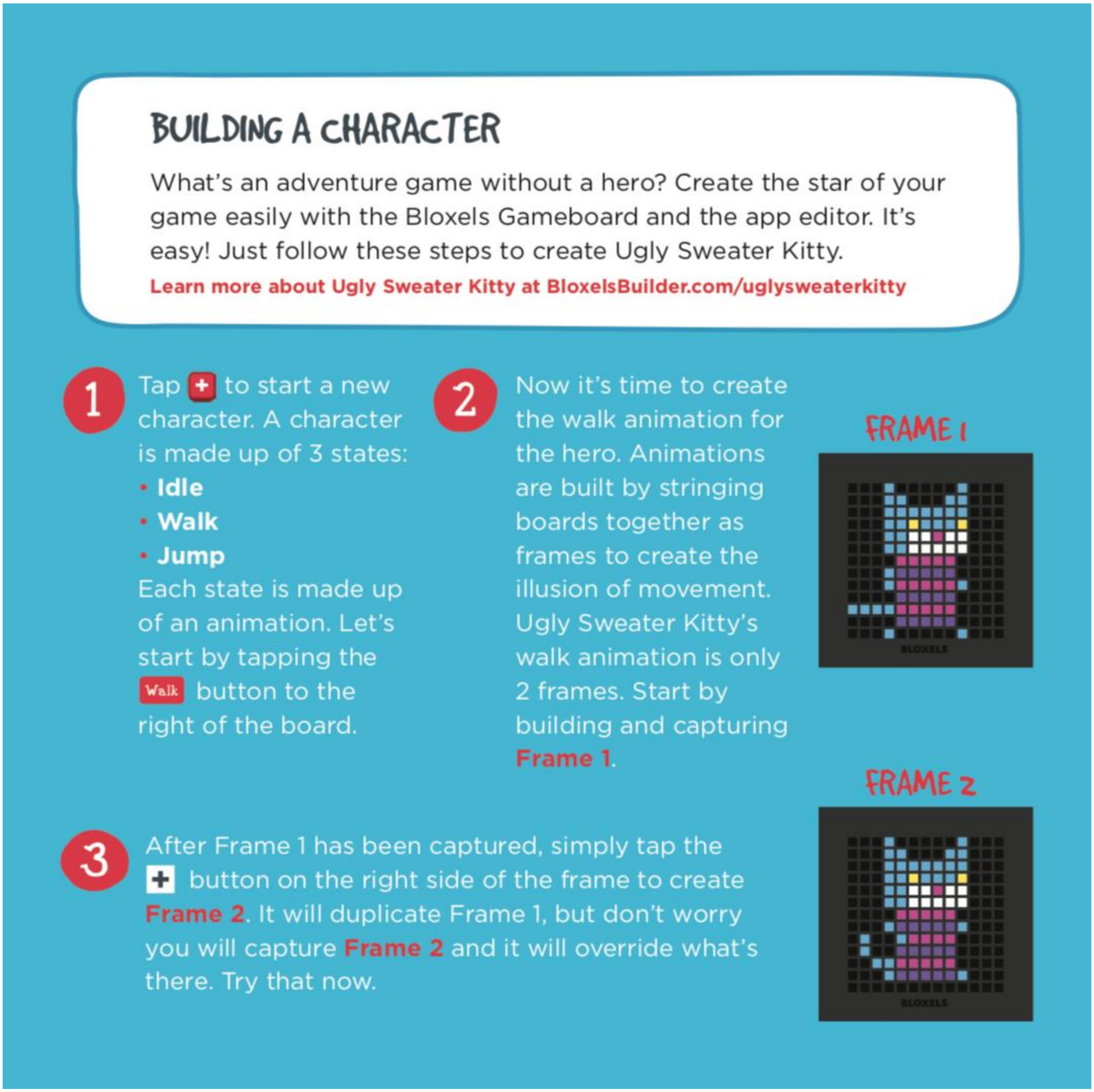
4. About 5 minutes before the end of the class, have students return their items and materials and share results with the class.

Assessment
<u>Activity Embedded Assessment</u>
Worksheet: Have the students record their character designs on the "Character Design" Worksheet. After students have finished their worksheet, have them use their designs in the Bloxels app.

Activity Extensions
Tell students they can animate their characters by watching the animate your character tutorial below: https://youtu.be/LY_-2zqgBFU

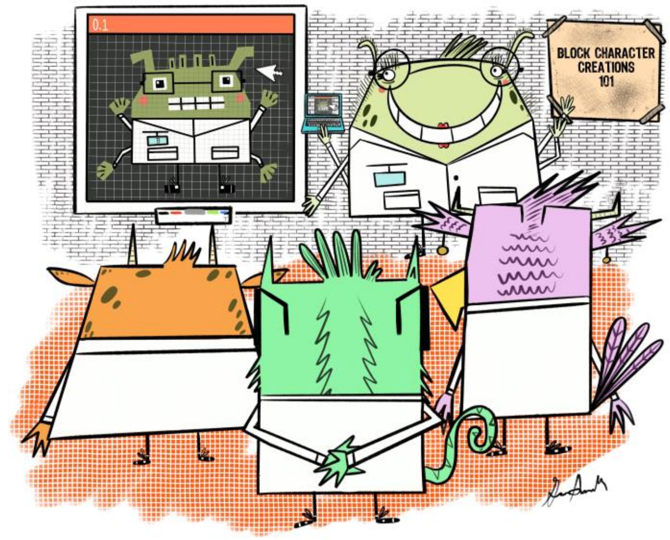
Activity Scaling
For lower grades or younger students, have them design their character by showing them pictures of Bloxel characters which can be found online to use as a guide. Simply search Bloxel characters using Google.

For higher grades, you can challenge the students to create as many characters as possible in the allotted time and saving them to the device to use later when creating a video game.



Name ____________________________ Date _________________________

Lesson 5: “Character Design”



1. Imagine:

- What does your video game character look like?
- What type of character are you thinking about? An animal? A person?
- What will they be wearing?

Write down a few ideas for your video game.

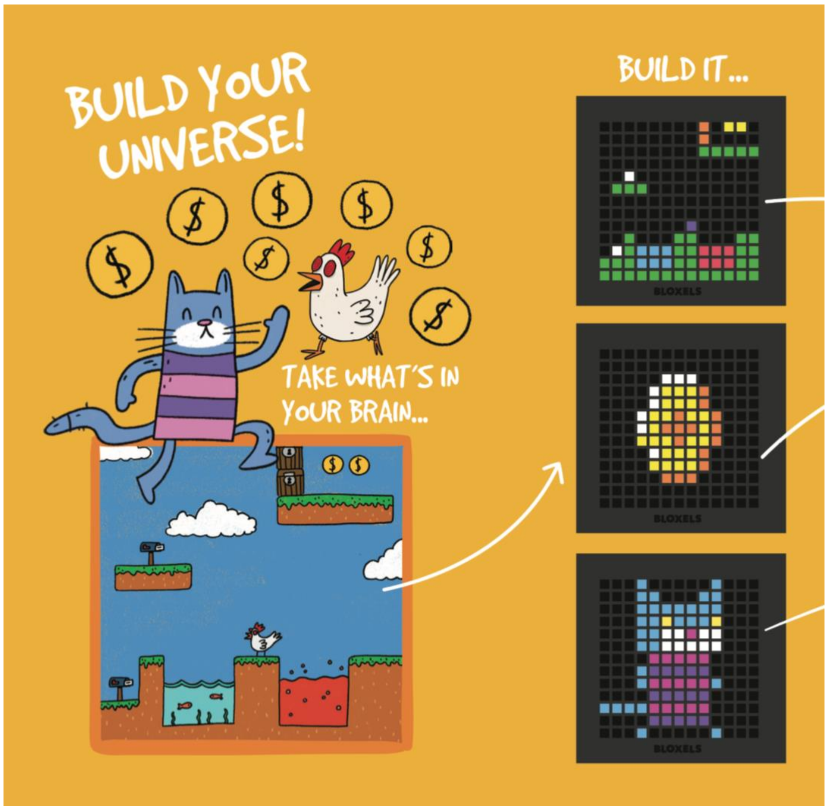
2. Plan: Select a solution. Use the grid below and color the squares to show what your character would look like on the Bloxel game board. You will use your drawing as a guide to build your background on the Bloxel board and then capture it using the iPad device.

Software Engineering

Lesson 6- Video Game Design with Bloxels
Ages 15-19

Overview
Bloxels is a hands-on platform for kids to build, collaborate, and tell stories through video game creation. Students can use colored blocks to design their characters and settings on a gameboard to tell their own amazing stories! The game board is scanned using the free iPad app to make the creation come to life!

Step 1: Unpack the Gameboard(s)
The 13x13 Gameboard provides the canvas for your students, a sandbox where their imaginations will unfold. Students will arrange the blocks within the boundaries of the board in order to create Characters & decorations (using the blocks as art) and Layouts (where the blocks have specific meanings).



Step 2: Examine the Blocks
When building game layouts, each block has a specific meaning. There are eight different block colors. A color guide is available for each student in the 13-bit Builder Guidebook, which may have been included with your purchase or can be printed for use in the classroom here.

Pink: Power-up **Purple**: Enemy **Blue**: Water **Green**: Terrain **Yellow**: Coin
Orange: Exploding Block **Red**: Hazard **White**: Story Block

Step 3: Install the FREE Bloxels Builder App
Visit the app store on your tablet or device and search "Bloxels" to download the latest version of Bloxels, or click here to for links and information on device support.

Step 4: QuickPlay & Familiarization
Want to dive in and see how the game plays? Hit **Quick Play** on the homepage page for the app. Pick a Character, Layout, and Decoration, and just play! You'll get a feel for the controls, and if you look close will start to understand how layouts and artwork combine to make a game from the 13x13 gameboards grid.

On this screen you can also test capturing game layouts (using the color guide on the previous page), or a game character (where the colors are used simply as art).

Step 5: Watch the Tutorial Videos
Bloxels has simplified the game build process to enable students to build games in minutes, where most game building software can take many hours if not days to have a playable game.

Watch all of the videos here to familiarize yourself with the game editor.

- Just Getting Started Tutorial: https://vimeo.com/322105023
- Building Your Game: https://www.youtube.com/watch?time_continue=1&v=YhVBdN-2Vr8
- Building Characters: https://www.youtube.com/watch?v=hBGpBiS-QKU
- Building Boards: https://www.youtube.com/watch?v=rZg9HJWHBgk

Step 6: Build Your First Game
Now that you have a better idea of how it works, click "Customize" from the quick start mode to start building in the full editor. You should set out to understand the 5 main areas of the builder, (1) Games, which use assets built in (2) Animations, (3) Backgrounds, (4) Characters and (5) Boards. Boards is essentially a library of assets that can be used pulled from to build in the other areas. You'll also notice in all of the areas that we've included pre-designed assets for you to use and edit to your liking.

Learning Objectives
1. Students will design and build a character, a background, and a video game in Bloxels Builder app.
2. Students will test and make changes to the video game they created to make improvements for game play.

Suggested Timeframe
60 minutes

Materials Required (each group of students need):
- 1 Device (iPad) with Bloxels Builder app installed
- The "Color Guide" from the Bloxels Guide Book for each group (see included PDF)
- Bloxels Gameboard: (one per group)
- Bloxels Blocks

Introduction/Initiation
"Have the students watch the "Just Getting Started Tutorial" on https://vimeo.com/322105023 to get an understanding of the video game design process.

Procedure
Before the Activity
1. Gather all supplies: 1 Bloxels Game Board, Bloxels Blockes, and 1 Device.

With the Students:

1. Pass out the Bloxels Gameboard, Blocks, the “color guide” from the guidebook (see PDF in this packet). For the prototype, students will need to create games using the gameboard and blocks associated with the Bloxels Builder app. The purpose of the different color blocks is so that the app can recognize and translate them into a playable game. Color Guides will show students the meaning of each colored block.
2. Note: With a limited time window, it may be more effective to have students create directly in the app versus on the Bloxels board, but we are going to go forward in the lessons with building with blocks first. This decision depends on your classroom and how experienced they are with the app and how many devices you have for your classroom.

Step 1- Open the Bloxels Builder App

Step 2- Click “Quick Start” and then go to “Games”

Step 3- Build a Game Layout

Building Your Game

Once you’ve created your first game layout, place the Bloxels gameboard on a white surface with good lighting. The app will recognize the Bloxels gameboard and capture the game. It’s possible that in the translation process, some of the blocks will require slight fixes. These can be completed with the in-app game editor.

We’ve found it may be helpful to watch the tutorial videos in advance and demonstrate use of the game editor to the entire class.

Students will need time to capture, edit, and test their levels. We’ve found that 20 minutes is typically enough time for a student to capture a Bloxels board into the App to make their own game.

Each of the colored blocks represents a different game element. A description of each is below:

Hazards (Red)

Coming into contact with a Hazard block will cause the player to lose 1 health. Losing 3 health means Game Over. Hazard blocks cannot be destroyed.

Terrain (Green)

Terrain blocks is the ground or walls of the game. It is safe for the player to touch. Terrain blocks cannot be destroyed.

Coins (Yellow)

Coin blocks are the games collectables and currency. Coming into contact with a coin block will add 1 coin to your bank. Coins cannot be destroyed.

Water (Blue)

Water blocks appear transparent. They will slow your character, along with grant infinite jumps while inside the block. Water blocks cannot be destroyed.

Enemies (Purple)

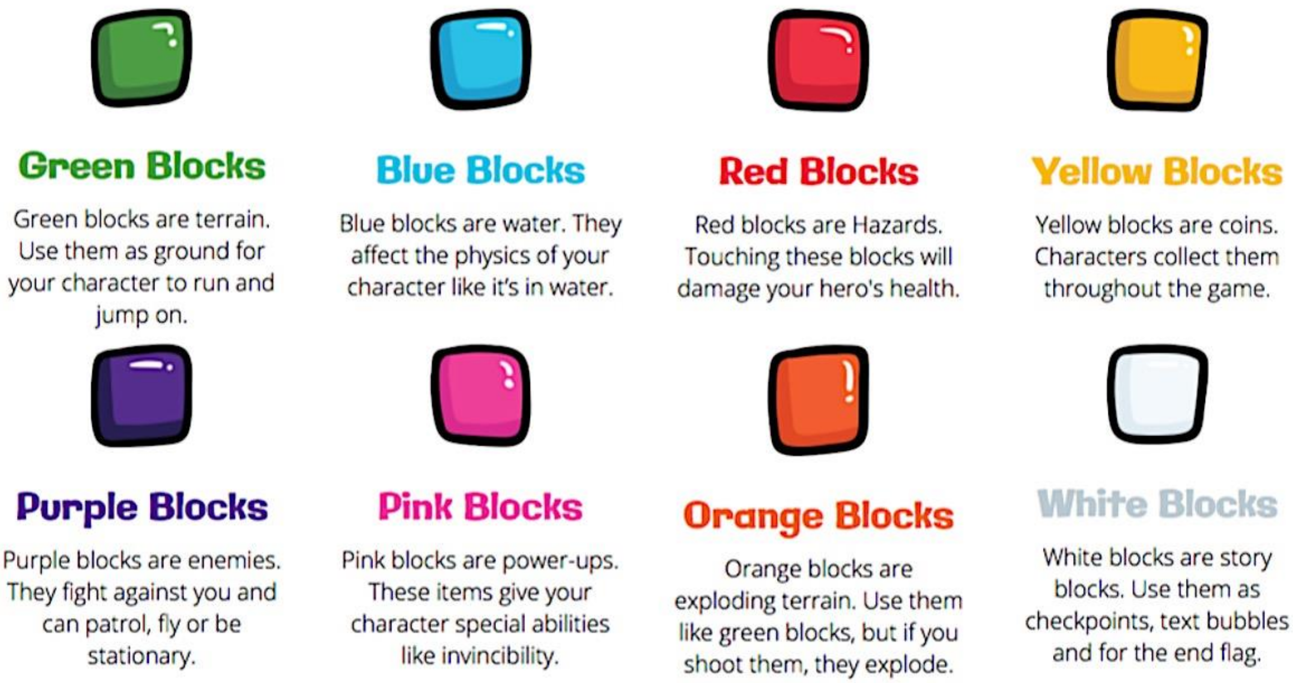
Enemy blocks will had enemies to your game. Coming into contact with an enemy will cause the player to lose 1 health. Shooting an enemy will destroy them. There are 3 different types of enemies to choose from (configurable through the Configure tab in the Game Editor).

Exploding (Orange)
Exploding blocks act a lot like Terrain Blocks, but can be destroyed by shooting them. Explosions will not harm characters or enemies.

Power-ups (Pink)
Power up blocks give the character special items to use in game. Power-ups can be picked up by shooting the block, then coming into contact with the hovering power-up icon. There are six power-ups in Bloxels:

- *Bomb:* Thrown by dragging down the A button. Destructible blocks will be destroyed if in the blast radius of the bomb. Bombs will not harm the player character.
- *Health*: Refills your health upon contact.
- *Jetpack:* Used by dragging down the B button. Allows the player to fly. Jetpacks have a limited amount of fuel, so use it wisely!
- *Shrink:* Used by dragging down A button. Using Shrink will shrink the character to the size of a single block. Shrink has a limited number of uses, so keep an eye on the meter!
- *Invincibility:* Destroy enemies on contact and become invulnerable to their projectiles. Character can still be harmed by Hazard blocks or falling out of the game.
- *Map:* Accessible through the Pause screen. Displays a more detailed version of the map.

Story (White)
Story blocks are the Checkpoints in your game. You can add Text bubbles to Story blocks through the Configure tab in the Game Editor. Story Blocks can be configured to be the Game End Flag. Coming into contact with a Story Block that is a Game End Flag will complete the game.



Activity Extensions

- Students can work on developing their game over time. As long as students save their work, the game development is continuous. Characters, Backgrounds, and animation can be developed as much as the player wants.

Activity Scaling
For younger students or older students that are struggling you have them complete this activity with a group and provide the materials for them to test ahead of time. If younger students want to start with Lesson 4- Video Game Background Design and then continue to Lesson 5- Video Game Character Design, then it will help them in this lesson.

Mechanical Engineering

Lesson 7- Parking Garages

Ages 6-11

Overview

The difference between architects and engineers can be confusing because their roles in building design can be similar. Students experience a bit of both professions by following a set of requirements and meeting given constraints as they create their own model parking garages. Teams experience the engineering design process first-hand as they design, build and test their models. They draw blueprints of their designs, select the construction materials and budget their expenditures. They also test their structures for strength and find their maximum loads.

Engineers and architects work together to design structures, and often their responsibilities overlap. Engineers must meet both requirements and constraints as they design and build structures.

Learning Objectives

1. Students will give examples of architects' and engineers' roles in building design.
2. Students will explain the difference between a requirement and a constraint.
3. Students will identify and draw a basic blueprint.

Suggested Timeframe

45-60 minutes

Materials Required (each group needs):

- Building Blocks
- 8 Model toy car
- 1 Small Book
- 1 Dry Erase Protective Sleeve for each student
- 1 Thin Expo Marker w/Dry Eraser attached for each student
- 1 "Parking Garage Budget" Worksheet with graph paper on other side to draw blueprint
  Students can place their worksheet inside the protective sleeve and use the dry erase marker to do their work.

Assessment

- Pre-Activity Assessment
- Activity Embedded Assessment
- Post Activity Assessmenent

Introduction/Initiation

"How do architects begin their designs? As they begin to design a structure, what information do architects need from their customers, or clients? One of the first things is what type of structure they will be designing and constructing. Architects design many different types of structures including houses, apartment buildings, skyscrapers and parking garages. Architects also needs to know how big the structure should be and what it will need to hold—or, what its use will be (people, cars, storage for large/small items, etc.). We call this information, provided by the client, the requirements of the project. Not only do architects need to meet these requirements, but engineers do as well.

The architect presents the original design for the project, but the engineer must work with the architect to meet the same requirements that the client expects while at the same time *ensuring that the building also meets all safety requirements (or, "meets code"). An example requirement for a parking garage would be a precise number of floors, or exactly how many parking spaces, as requested by the client.*

Once the architect and engineer are given the requirements by the client, the architect begins drawing up the design for the structure. The detailed drawings that engineers and architects create have a special name—blueprints. The architect's blueprint has the dimensions of the structure included in the drawing so that the engineer knows the size of the structure and can build it following the architect's specifications (see Figure 1). Once the architect has completed the blueprint, the engineer takes that blueprint and examines the design to determine what materials should be used to best support the weight of the structure.

Before starting construction the engineer must clear the final design with the client and the architect. Once the engineer gets the go-ahead, construction begins. The final step in engineering is testing the structure. Engineers must always make sure that a building is safe before opening it to the public or turning it over to the client for other use.

For this activity, the client is your teacher, and the desired structure is a parking garage. The requirements are that the parking garage must be able to hold either eight toy cars and 1 small book and must have a ramp, which will move cars to the top level of the garage.
The constraints are that the height must be at least 10 cm; the parking garage must be under 30 cm in length and 30 cm in width, but longer than 15 cm and wider than 15 cm. The budget, another constraint, for the parking garage is $50. A budget sheet will be provided with the list of available materials and their individual prices. To ensure that you do not run out of money before completing your structure, make sure to only purchase the materials that you know you need! You can always add more materials if your budget allows. We have two days to work on our projects, so take the time to think through your ideas and create a great design!

Procedure
Before the Activity
1. Gather all supplies.
2. Get 1 “Parking Garage Budget” Worksheet, 1 Protective Sleeve, 1 Thin Expo Marker/Eraser for each group.

With the Students:
1. Conduct the Introduction/Motivation section with the class. Show them all the materials available for the building project.
2. Present students with the following building requirements and constraints. Answer any questions about what they can do in their designs.

Requirements: Parking garage must be strong enough to hold at least 1 small book (or 8 toy cars) and have a ramp going up to the top level.

Constraints: Parking garage must measure between 15 to 30 cm long and 15 to 30 cm wide; be greater than 10 cm tall; and be made for $50 or less.

3. Divide the class into groups of two students each and hand out graph paper.

4. Direct the teams to brainstorm ideas for designing their model parking garages, as if they are architects. Have them draw their final designs on graph paper, including the structure dimensions (total height, width, length), their names and the date. If desired, have each group choose a name for its "architecture/engineering firm" and include that on the graph paper, too.
5. Have the student teams finish their drawings and get client (teacher) approval.
6. After drawing are approved, give each team a worksheet and explain that they are now working as engineers and must choose which materials to use while staying within a $50 budget. As necessary, review how to accurately calculate the total cost of project materials.
7. Return the blueprints to the student teams. Give them their worksheets with the materials they "ordered," and subsequently "purchased."
8. Give students time to construct their parking garages using the materials they purchased. As they build, permit them to purchase more materials—if they have funds left in the budget.
9. Using the books (or toy cars), test the parking garage for strength and have each group determine the maximum load its structure can hold. To determine maximum load, add on small books until the structure collapses. For this activity, call the number of books added prior to the last book that causes the structure to collapse the *maximum load*. Have each team record its results on the classroom board.
10. If some structures do not hold any weight, and the team has money remaining in its budget, permit them to redesign and reconstruct the structure.
11. To conclude, as a class, go over the testing results. Determine which model parking garage(s) held the most weight and prompt students to evaluate the stronger garages to draw some conclusions about what design decisions and building techniques helped to make them strong.

Assessment

<u>Pre-Activity Assessment</u>

Question/Answer: Ask students questions and have them raise their hands to respond. Write answers on the board.

- Who participates in the design of a parking garage? (Answer: Architects, and ultimately engineers, do the designing; requirements and constraints are generally set by the client.)
- Who is responsible for making sure that buildings and structures are safe? (Answer: Engineers)
- Who is in charge of the aesthetic design of a structure? (Answer: Architects)
- What are some practical materials that would be used to build a real parking garage? (Possible answers: Cement, concrete, steel, asphalt, rebar, gravel, wire, etc.)
- What type of client would need a parking garage? (Possible Answers: A town, an airport, a hospital, shopping mall owners, office building owners, etc.)

<u>Activity Embedded Assessment</u>

Blueprint: Have students complete a blueprint of their parking garage design prior to building the garage. Blueprints should be turned in and approved before giving out materials. Have them draw their final designs on graph paper, including the structure dimensions (total height, width, length), their names and the date.

Worksheet: Have the students record budget on their “Parking Garage Budget” Worksheet. After students have finished their build they should turn in the list of items needed that they would like to purchase.

Post Activity Assessment

Blueprint Sharing: Ask students to share their blueprints with the class, and discuss their approach to meeting the requirements and constraints. Have students share what made creating the blueprint challenging and which parts of designing the blueprint they most enjoyed. If desired, discuss with students how engineers and architects now use computers to create their final blueprints (e.g., using specially-designed CAD — computer aided drawing — software).

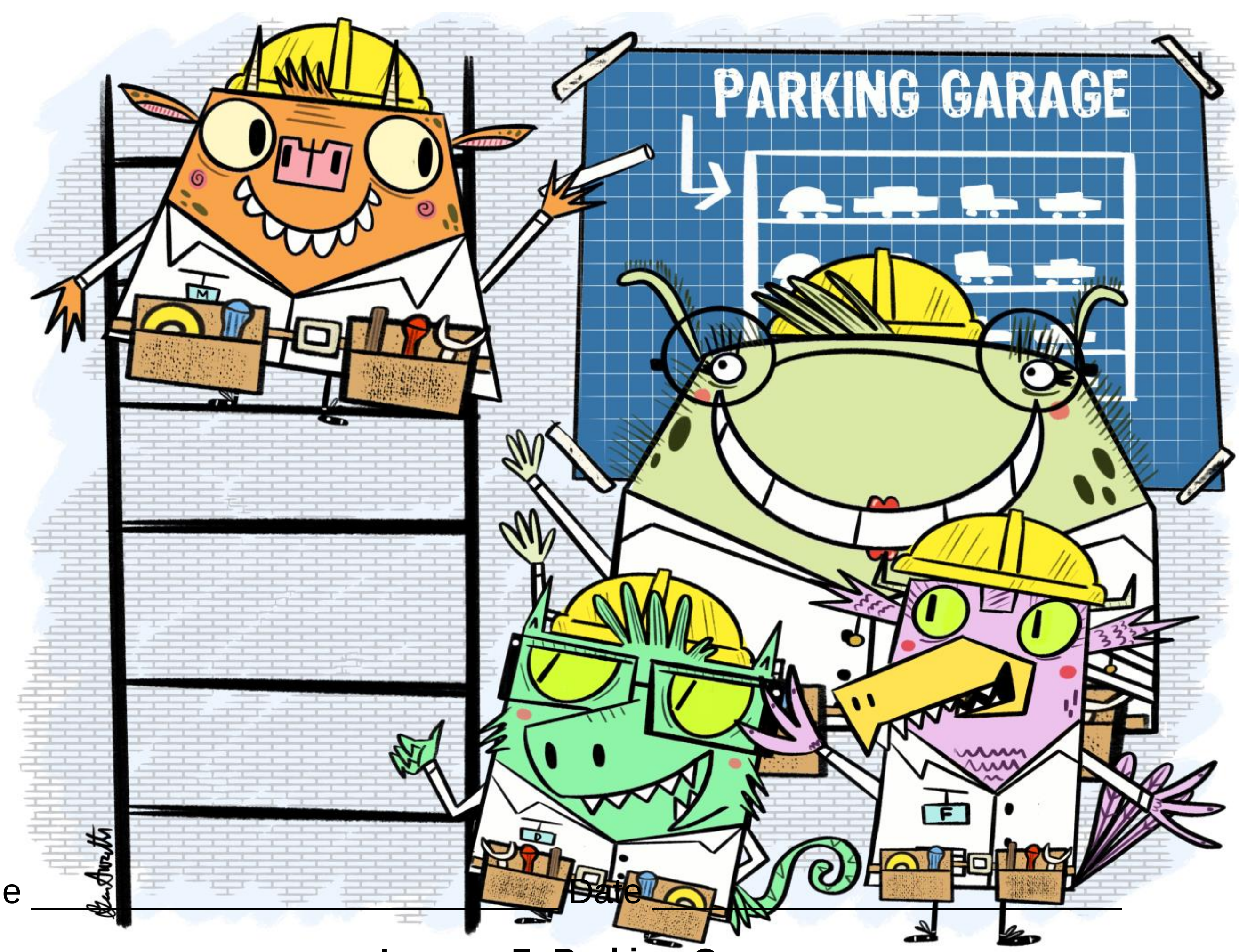
Activity Extensions

- Have students research to find the real-world final cost of a making a parking garage and what materials were used.
- Have students research a structure that they really like and write a short (one-page) report about the architecture and engineering involved.
- Ask a local architect to come in and talk with the class about projects they are currently working on. Have them bring in blueprints of their projects to show the students.

Activity Scaling

For lower grades, give students a certain set amount of materials for construction rather than using the budget worksheet. Or, simplify the activity by giving the students fewer constraints.

For older grades, give students more requirements and/or constraints. One additional requirement could be to add another level (or two) to the parking garage.



Name ______________________________ Date ____________________

Lesson 7: Parking Garages

1. Imagine: What does your garage look like? Draw your final designs on graph paper, including the structure dimensions (total height, width, length), their names and the date. If desired, have your group choose a name for its "architecture/engineering firm" and include that on the graph paper, too.

2. Plan: Use the back of the page and decide what blocks you will be using and calculate the price you will spend for materials. You can not spend more than $50.

Budget Planning

Instructions: Use the chart below to figure out the coast to build your model parking structure. Stay under budget! To make sure that you do not run out of money before completing your structure, only purchase the materials that you know you will need!

Material	Cost	Quantity	Total Purchase ($)
Wood Cylinder	$1 per block		
Wood Bridge	$5 per block		
Wood Cube	$2 per block		
Square Cylinder	$1 per block		
Short Wood Cylinder	$5 each		
Flat Wood Rectangle	$10 each		
Large Trapezoid	$3 each		
Small Trapezoid	$1 per block		
Large Triangle	$2 each		
Small Triangle	$1 each		
Half Circle	$3 per block		
Do not exceed $50 ➔		TOTAL	

3.

Create & Build: Once you've calculated your budget, use the building materials to construct your parking garage. Follow the requirements:

- The requirements are that the parking garage must be able to hold either eight toy cars and 1 small book and must have a ramp, which will move cars to the top level of the garage.
- The constraints are that the height must be at least 10 cm; the parking garage must be under 30 cm in length and 30 cm in width, but longer than 15 cm and wider than 15 cm. The budget, another constraint, for the parking garage is $50.

4. Test & Evaluate: Did your garage meet the requirements? Was it able to hold 8 toy cars and a small book? Is it at least 10 cm high? Did you spend less than $50?

Lesson 8- Roller Coasters
Ages 12-14

Overview

During the design of model roller coasters, students encounter many of the same issues that real-world roller coaster engineers address. In order to build working roller coasters, students must recognize the constraints placed on their designs and the design of real roller coasters by the fundamental laws of physics. Students learn that their ability to understand and work within these constraints is paramount to the success of their roller coasters.

Learning Objectives

1. Students will explain why it is important for engineers to know how roller coasters work.
2. Students will explain in physics terms how a roller coaster works.
3. Students will identify points in a roller coaster track at which a car has maximum kinetic energy and maximum potential energy.
4. Identify points in a roller coaster track where a car accelerates and decelerates.

Suggested Timeframe

60 minutes

Materials Required (each group needs):

- 2-meter (6 foot) long foam tube (pipe insulation) cut in half lengthwise (Usually, one side of the tube comes perforated, making it easy to use scissors to cut through the perforation and the other side of the tube to form two halves, essentially making two long channels perfectly shaped to hold marbles; thus, one cut tube provides the track material for two groups; see **Figure 1**
- Marbles
- Paper or plastic cup
- Roll of masking tape
- Set of markers, crayons or pencils
- Blank sheet of paper
- Stopwatch (google stopwatch on compueter/device)
- 1 Dry Erase Protective Sleeve for each student
- 1 Thin Expo Marker w/Dry Eraser attached for each student
- 1 “Roller Coaster” Worksheet
  Students can place their worksheet inside the protective sleeve and use the dry erase marker to do their work.

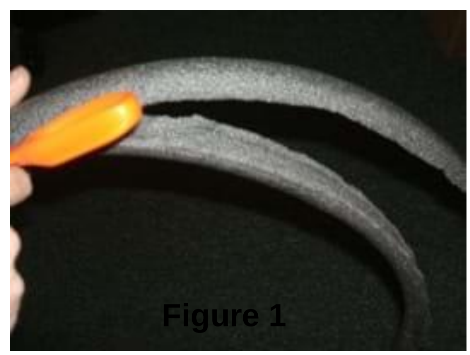


Figure 1

Assessment

- Activity Embedded Assessment

Introduction/Initiation

“During today's activity, you are going to design your own model roller coasters using foam tubes and marbles. I'd like for you to start by drawing your roller coaster on paper before building it. Along with your drawing, give your roller coaster a fun and descriptive name and make a sign for it.

(At this point, show students photographs of some real roller coasters to help them imagine the possibilities for their own coasters. See examples of some of the best current roller coasters in the country at https://www.ultimaterollercoaster.com/coasters/pictures/)

When engineers design objects and structures, such as the appliances in your homes and other products you use, bridges and roadways, skyscrapers and other structures like amusement park *rides, or even bicycles and chair lifts at ski resorts, they work within what they call "constraints." Constraints are project requirements and/or limitations. Engineers must take into consideration these constraints in order to come up with successful design solutions.*

In the case of designing roller coasters, what might be some constraints that engineers would have to consider? (Let students think about this and make some suggestions.)

Yes, they might have some practical limitations, such as available or preferred building materials, a construction budget and timeframe, safety measures for users, ongoing maintenance requirements and/or anticipated weather conditions. The amusement park client may also give requirements for the type of movement they want for the ride, such as upside-down loops, corkscrews, specific degree turns, length of drops or maximum speed, or safety assurances for users (safe for people taller than four feet high). Another basic constraint that always applies is consideration of the natural physical laws that exist in our world, such as the limits of gravity and effects of slope, speed and friction. This is an example of how an engineer's understanding of the fundamental laws of physics is very important to the success of a project. Coming up with a design solution that takes all these factors into consideration and works reliably, safely and as intended is what engineers do.

When designing your roller coaster, what are the physics concepts that you have learned that will be helpful and very important to apply? (Listen to student ideas. You can ask them how do roller coasters start? How do they get their energy? Expect them to suggest ideas from what they've learned in school about gravitational potential energy, kinetic energy, gravity and friction.)

That's right, all true roller coasters are entirely driven by the force of gravity. The excitement of a ride comes from the ongoing conversion between potential and kinetic energy, which we know from the law of conservation of energy. Friction is important to slowing down roller coaster cars and acceleration plays a role in the experience provided by roller coaster cars as they move along a track.

And how do these concepts translate to your challenge to design a roller coaster that provides a thrilling experience that is safe for riders? (Listen to student answers. Expect to hear them bring up the following points, which they must understand in order to build and analyze their model roller coasters:

- *The top of the first hill must be the highest point on the roller coaster.*
- *Cars move fastest at the bottoms of hills and slowest at the tops of hills.*
- *To avoid falling, cars must have a certain velocity at the tops of loops.)*

The first hill must be the highest point or the roller coaster won't work. If a car is not moving fast enough at the top of a loop it will fall off the track. Pay attention to the friction between the car and the track, making it as small as you can so the cars move fast enough to make it through the entire track. Let's get started!

Procedure

Before the Activity

3. Gather materials and make copies of the worksheet and scoring rubric.
4. Cut each tube in half lengthwise, so each group receives one length of tube that is channel-shaped to serve as the roller coaster track for the marbles (cars). Use scissors or a utility knife to cut through the perforated side of the tube to form two halves. Give each group one of these halves. This process is shown in Figures 1 and 2.

With the Students:

1. Divide the class into engineering groups of three or four students each.

2. Hand out the scoring rubrics for the class competition. The list of creativity points provides students with guidance as to the coaster features (height, turns, loops and corkscrews) that are desired in the design and the list of performance points provides a way to judge the safety of the coasters. Tell the students: In our roller coaster models, the glass marble simulates a normal car, the wooden marble represents an empty car, and a steel marble represents a full car. Your team will earn points for each type of marble (passenger load) that successfully completes your track and lands safely in the cup. A class competition will determine the most innovative and successful roller coasters.
3. Have groups start designing their roller coasters, brainstorming and sharing ideas and agreeing on a design. Have students draw their roller coasters on paper, name them, and make signs. Allow up to 30 minutes for this. Look over their drawings to ensure that their proposed designs are physically possible. If not, point out those aspects of the roller coaster design that they may want to rethink. Give them time to iterate their designs.
4. Give each group a foam tube track, masking tape and cup, and let them build their roller coasters using classroom materials. Expect students to be able to build their first design in 10 minutes or less. Use the cup to catch the marble at the track end.
5. Give students marbles so they are able to test their roller coasters and make any necessary changes. This is the most time-consuming step and students may need up to 45 minutes to redesign their tracks.
6. Hand out a stopwatch to each group and give them time to complete the worksheet, in which they determine certain specifications of their roller coasters.
7. Start the class competition by telling the students: Similar to what you did today, engineers create small-scale models to help them test and analyze their structural designs. For example, the engineers who designed the Golden Gate Bridge in San Francisco were pioneering new suspension bridge design theory. They verified their complex calculations (all done without computers in the 1930s) of the forces it would need to withstand by performing tests on a steel tower model at 1:56 scale. That's 56 times smaller than one of the actual bridge towers. The tests confirmed that the tower calculations of the anticipated forces, including wind/earthquake deflections, were sound—and the bridge still stands today, more than 75 years later.
8. Have each group present its roller coaster model to the class. Use the scoring rubric to evaluate the roller coaster model designs. Discuss the results as a class, as described in the Assessment section.

Assessment

<u>Activity Embedded Assessment</u>

Worksheet: Have the students measure the length of their roller coaster (i.e., can measure the distance of the length of tubing) and the time it takes for the marble to complete the track. Ask students to calculate the velocity of the marble in m/s as well as in ft/s.

Have each group identify some critical points of the roller coaster as well as other specifications such as height and the number of loops and turns.

Activity Scaling

For lower grade levels, eliminate much of the physics exploration behind the lesson content. Have students build their own roller coasters and discover for themselves many of the concepts that are discussed in detail at higher grade levels (such as energy conservation, friction and gravity), and they may also be capable of understanding some basic explanations of friction and gravity.

For higher grades, introduce equations for potential and kinetic energy so students can calculate both forms of energy and verify the law of conservation of energy. Have students explore loops along with the concept of critical velocity. Have students find the starting height of a roller coaster necessary to complete a loop of a given height.

Troubleshooting Tips

If students have difficulty getting their roller coasters to work, revisit the basic physics considerations:

- Make sure that the highest point of the roller coaster is at the beginning.
- Reduce friction by checking that the track is wide enough for the marbles to pass.
- Any track deformation occurring when marbles are rolled down the track results in a loss of energy, so make the roller coaster as stable as possible by taping it to supports (textbooks, walls, desks, chairs, shelves) at several points.

Name ____________________________ Date _________________________

Lesson 8: "Roller Coasters"

1. Imagine & Plan: What does your roller coaster look like? Draw a picture of your roller coaster in the box below and answer the following questions.

Height in cm: ______
# of Loops: ______
# of Corkscrews: ______
# of Turns ______

3. Create & Build: Use the tubing and masking tape to create a roller coaster.

4. Test & Evaluate: Did your marble make it all the way to the end of the track? Test different size marbles and record the time it takes to make it to the bottom.

Test Result #1	Test Result #2	Test Result #3	Test Result #4
Velocity= cm / time			

Mechanical Engineering

Lesson 9- Right on Target: Catapults!
Ages 15-19

Overview
Students experience the engineering design process as they design and build accurate and precise catapults using common materials. They use their catapults to participate in a game in which they launch Ping-Pong balls to attempt to hit various targets.

The engineering design process is an important aspect of solving engineering challenges, regardless of their nature. This process refers to the steps of designing, building, testing and redesigning a product in order to achieve solutions that adequately meet the objectives. Whether designing a rocket to take us to the moon, an artificial leg for a runner, or the coolest new toy for kids, engineers follow the steps of the engineering design process.

Learning Objectives
1. Employ the engineering design process to create a solution to a given problem.
2. Design and build catapults using materials found at home.
3. Explain the meaning of projectile motion, accuracy and precision.

Suggested Timeframe
45-60 minutes

Materials Required (each group needs):
- 3 sheets of paper (for brainstorming)
- Crayons or Markers
- Cardboard coaster base
- Targets
- 48 in. of Masking tape
- 1 Plastic spoon
- 3 Rubber bands
- 8 Popsicle sticks
- 4 straws
- 1 Ping-Pong ball
- 1 Dry Erase Protective Sleeve for each student
- 1 Thin Expo Marker w/Dry Eraser attached for each student
- 1 “Parking Garage Budget” Worksheet with graph paper on other side to draw blueprint *Students can place their worksheet inside the protective sleeve and use the dry erase marker to do their work.*

To share with the entire class:
- Targets (10 points, 50 points, 100 points and 200 points)

Assessment
- Pre-Activity Assessment
- Activity Embedded Assessment
- Post-Activity Assessmenent

Introduction/Initiation
“Today, we are going to use our engineering skills to design catapults for a game! Did you know that many toy companies employ engineers to design toys? We will be working and having fun just like

those engineers!
Using some everyday materials, we will create catapults that can launch Ping-Pong balls in a precise and accurate way. If your catapult launches Ping-Pong balls so that they all land in the same place but do not hit the target at all, is that an example of accuracy or precision? (Answer: Precision.) What if all your Ping-Pong balls hit the target, but in different places on the target, is that an example of accuracy or precision? (Answer: Accuracy.) What if all your Ping-Pong balls hit the target in the same place? (Answer: That demonstrates accuracy and precision!)

Now that we've reviewed those terms, we still need to figure out how to design a catapult that is both accurate and precise. Let's start by walking through the process engineers use to go about solving problems like this. Whenever engineers are faced with a challenge, similar to the one we've just discussed, they use a tool called the engineering design process to help them come up with good solutions.

The first step in this process is to identify the problem or challenge. For us, that's easy—we need to develop a machine that can launch Ping-Pong balls in an accurate and precise way. The next step is to brainstorm ideas. You can brainstorm in many ways, but a common method is to draw and discuss ideas as a team. After brainstorming, the best one or two ideas are chosen and formed into an initial design. These designs are drawn on paper, with all individual parts clearly labeled and a list of necessary materials. Once this design is complete, materials are gathered and prototype construction begins. Usually, it is during the construction of this first "prototype" design when unforeseen problems with the design are discovered. Even engineers who have been designing for 20 or 30 years go through this process. So do not expect your catapult to work perfectly the first time! The point is to learn from your mistakes, make changes to the design, and perform lots of tests. After many tests and adjustments, the catapult will eventually work.

During this activity, we will design, build and test until we develop machines that complete the challenge objectives!

Procedure

Before the Activity

1. Gather all supplies. Get 1 “Catapult” Worksheet, 1 Protective Sleeve, 1 Thin Expo Marker/Eraser for each group.
2. Set up a table with four targets: 5 + 5 points, 10 + 10 points, and 20 points. Make simple targets using cardboard or foam core board. The targets will be used for the game at the end of the activity. Place targets with lower point values closer to the launching area.

With the Students:

1. Review the following information with students:
   After completing our launching machines, or catapults, we are going to play a game in which we aim and fire our catapults, trying to hit different targets.Hitting the targets earns you different amounts of points: 10, 50, 100 and 200. We want our catapults to be both accurate and precise in order to hit the maximum number of targets. In addition to making accurate and precise catapults, we also want to make sure that our catapults shoot the Ping-Pong balls far enough to hit the targets. After launching, the balls follow what engineers call "projectile motion." When launching a projectile, a 45º angle causes the object to travel the farthest distance. Keep this fact in mind when you are designing your catapult's launching mechanism.

   To propel the Ping-Pong ball long distances, significant forces will be applied to the structure of your catapult in many different directions. Let's review what we learned about force. If the launching part of your catapult is held with a lot of force, your projectile (the Ping-Pong ball) will also be launched with a lot of force. If your Ping-Pong ball is not making it to the target, should you increase the force on the launcher or decrease it? (Answer: Increase.) What if you launch your Ping-Pong ball and it goes way past all the targets? Should you increase or decrease the force on the launcher for the next trial? (Answer: Decrease.)

To make sure that your structure can withstand all of these varying forces, consider using lots of triangles in the frame of your catapult. A triangle is the strongest geometric shape because its sides cannot move unless their lengths change. This means that if you make a triangle using Popsicle sticks, one of the Popsicle sticks would have to break in order for the shape to change. On the flip side, a square or a rectangle can easily compress and change shape into a diamond or other type of quadrilateral without any of the sides changing length. These shifting shapes could lead to a lot of stress on the joints and might cause your catapult to collapse as you try to launch a Ping-Pong ball.

Now that we've covered the science and engineering principles behind catapult design, it's time to apply these concepts and have some fun!

Figure 1. Example completed catapults

2. Divide the class into groups of two or three students each.
3. Hand out the worksheets.
4. Direct students to follow the steps detailed on the worksheet. Guide student groups to brainstorm multiple designs and then choose the best design to draw and label. Do not give the students materials until after they have completed their designs and developed a materials list. Give teams who work well together "teamwork tokens," which give the group one extra shot during the game.
5. Give students time to build their initial catapult designs.
6. Have groups test their catapult designs, make adjustments and refine their designs(as per the steps of the engineering design process) until it is time to play the game.
7. Collect all of the catapults at the front of the classroom.
8. Permit each team to make three shots at each target. Groups with a "teamwork token" may exchange it for one extra shot during the round of their choice.

9. Add up the points from each round and announce the winning team.

Assessment

Writing Assignment: Assign students to write short paragraphs that answer the following problem question: You are a mechanical engineer who has been challenged to design a machine that can launch a T-shirt 150 feet. What steps would you follow while trying to come up with a solution (do not describe a solution, describe the process you would use to try to come up with a solution)? Have several students read their ideas to the rest of the class. When you discuss the "engineering design process" during the introduction, compare it to the processes developed by each of the students.

Activity Embedded Assessment

Worksheet: Have students complete the Right on Target: Catapult worksheet to gauge their mastery of the subject matter.

Post-Activity Assessment

Class Discussion: As a class, analyze the characteristics of the winning catapult. What made this catapult more accurate and precise than the others? Do you see any simple ways to improve the performance of the catapult?

Activity Extensions

Adjust the mass of the Ping-Pong ball by taping pennies to it. Record how far the catapult launches different masses. Make graphs of this data by placing the number of pennies on the x-axis, and the distance the catapult launched the ball on the y-axis. What does the graph look like?

Activity Scaling

For lower grades, give students more direction in designing and building their catapults. For example, develop a design in advance, then guide the students through the basic construction of the frame of that design, so as to limit student design variables to only the launching mechanism.

For more of a challenge, have students measure the angles at which the catapult releases the Ping-Pong balls and the distances the balls travel during the testing. Adjust the catapult at least twice, each time measuring the angles of release and the distance traveled. In this way, students determine the optimum angle of release to send the Ping-Pong ball the farthest.

Name ____________________________ Date _________________________

Lesson 9: Right On Target: Catapults!

Problem: You are an engineer who specializes in designing cool toys and machines for games. You were recently contacted by the Super Fun Toy Company to help design a machine called a catapult for a game that will launch Ping-Pong balls at a series of targets. To ensure that children and adults alike will love the game, you need to make sure the catapult is both accurate and precise.

Constraints: The only building materials available to you are listed below.
Materials**:**

Popsicle Sticks
Masking Tape
Straws
Rubber Bands
Plastic Spoons
Cardboard Base (1 per group)

Imagine: Brainstorm several ideas you have for how to use the above materials in your catapult. Draw pictures!

Design: Draw out your group's best catapult design. Be sure to label where you will use all of the different materials (Popsicle sticks, tape, plastic spoon, etc.).

Build: List how much of each material you will need to build your catapult. Once your design and materials list are complete, you may collect materials from your teacher. Make sure you labeled the materials in your design!

Item	**# needed**
Cardboard Base	1
Popsicle Sticks	
Masking Tape	
Straws	
Rubber Bands	
Plastic Spoons	

Test: How well did your catapult work? What are two ways you can change your catapult to make it better? List these ideas here, and then start over at the beginning of this sheet.