Energy Has Many Faces

Created for SPICE by Elan Dalton and Nate Stewart - May 2009

Lesson 1: Where Does Energy Come From?

KEY QUESTIONS:
What is energy?
Where does electricity come from?
How much energy is involved in producing usable energy?
What are alternative energies?

SCIENCE SUBJECT: Physical Science

GRADE LEVEL: 6-8

SCIENCE CONCEPTS: Energy conversion and transfer

TIME ESTIMATES: A 50-minute period

LEARNING STYLES: Visual, auditory and kinesthetic

VOCABULARY:
1) energy – the ability to do work or cause a change
2) electrical energy – the flow of electrical charge (electricity)
3) mechanical energy – the energy that causes movement
4) thermal energy – the energy caused by the total movement of individual particles in matter
5) energy conversion – changing one type of energy into another
6) heat – the flow of thermal energy
7) turbine – a rotary engine that extracts energy from a fluid/gas flow
8) generator – a device that converts mechanical energy into electrical energy
9) conservation – careful use of resources to reduce damage to the environment through such methods as composting or recycling materials
10) fossil fuel – no renewable energy source, such as oil and coal, formed over millions of years from the remains of dead plants and other organisms
11) renewable energy – energy formed from the Earth's natural resources, such as wind and water, that can be regenerated
12) nonrenewable – any energy resource that can not be regenerated

LESSON SUMMARY:

Where does our energy come from? We all take the ease of flipping a light switch for granted, but what's the story behind turning those lights on? It takes a lot of energy to produce energy. This lesson is designed to develop your students' appreciation for the fuel and electricity that goes beyond the pump or outlet. They will learn the extensive processes and effort that it takes to convert the Earth's natural resources (i.e. coal, oil) into usable energy (electricity and fuel). Students will interactively demonstrate how life style choices affect the demands for energy production, and the environmental consequences involved.

STUDENT LEARNING OBJECTIVES:

After completing this lesson students should:

1) Understand the difference between energy and electricity
2) Understand and appreciate the process of creating and delivering usable energy
3) Understand the scope of energetic "requirements" of each individual
4) Understand that energy can be stored are converted into usable forms
5) Understand that humans' lifestyle choices (including their own) have a cumulative impact on the environment
6) Understand that the Earth's natural resources are limited
7) Understand that they can have a conservative role based on the choices they make on a daily basis

MATERIALS:

ESSENTIAL:

1. 1 set per student - *What's your impact?* Activity cards

SUPPLEMENTAL:

1. Poster paper & markers –brainstorming storyboards

BACKGROUND:

American, and other develop nations, lifestyles intimately rely on the availability and remarkable convenience of electricity and fuel. The primary source of this energy comes from expendable fossil fuels, which are projected to become depleted within the next 100 years. In fact, 85% of energy consumed in the US comes from these fossil fuels (the remaining 15% being provided by nuclear and renewable, mainly hydroelectric, sources). The motivation behind finding effective alternative energy is obvious. Understanding the current processes involved in producing energy is essential to finding a solution to the problem. For example, coal must be mined, transported, refined, and burned to drive the turbines responsible for producing the electricity that then must be distributed through power lines to the homes where it will finally be used. The process itself requires energy and man-power at each step. Appreciating the complexity and effort involved in producing consumable energy causes one to be more mindful of wasted and unnecessary energy use.

The conversion of mechanical energy into electrical energy is the underlying principle in producing electricity. The energy of motion must first be captured before it can be transformed. Most contemporary power plants use steam to provide the mechanical energy. A heat source (burning coal or natural gas) boils water to produce steam. As the steam rises it passes through the blades of giant turbines, causing them to spin. The spinning blades are connected to a drive shaft that spins a generator which causes relative motion within a magnetic field, producing electrical current (electromagnetic induction). Thus, electricity is produced and subsequently distributed through power lines.

ADVANCE PREPARATION:

- Prepare *What's your impact?* activity cards:
  - Print and cut out a page of "lifestyle" cards for each student (print front and back to have pictures on one side and descriptions on other)
  - Print and cut out "energy sources" cards (front and back) in excess, approximately one sheet for every 4 students

PROCEDURE WITH TIME ESTIMATES:

Introduction: probing your students' knowledge of where energy comes from (25 minutes)

Initiate interest in the topic by asking your students to write down a few things they enjoy doing. Challenge them to read from their list any activity that doesn't require energy directly, and furthermore, indirectly through its production, transportation, and use. (5 minutes)

Small groups of students should then be utilized to brainstorm stories explaining where energy comes from. Poster sheets allowing groups to illustrate a storyboard are optional. (10 minutes)

This should effectively lead into a teacher-guided discussion of how our energy is produced for our use, including both electricity and fuel. Forms of energy (emphasis on mechanical and electrical), energy transfer, and converting energy to different forms should all be addressed in the discussion. (10 minutes)

Activity: *What's your impact?* (25 minutes)

Part 1: Livin' the dream:

Tell your students it is their lucky day, they have all won the lottery and now get to choose the lifestyle they want to adopt. Distribute to each student a set of "lifestyle" cards and explain the following "rules": 1) each student picks at least one Transportation, Housing, and Food cards, and 2) any number of Entertainment cards can additionally be selected. Once each student has selected their lifestyle, have volunteers explain their selections to the class, including what factors they considered during the selection.

Part 2: Got energy?

Now explain that the game is not over, rather they have to find a way to get the energy to power their selected lifestyle. Make available the "energy sources" cards, having students first calculate how much and what type of energy they need for their lifestyle, and then deciding on what type of energy they want to use. Again, allow students to share what types and quantities of energy they chose.

Part 3: The catch

Unveil the "Earth cost" prices of each type of energy source. Have the students total the number of Earths it would take if everyone in the world lived the lifestyle they have chosen. Discuss the implications of living an energetically demanding lifestyle and the feasibility of doing so with our current state of energy sources.

Part 4: Back to reality

Challenge the students to change their lifestyle so that they could power it with energy sources that cost a total of only 1 Earth. Discuss with the class the possibility of such changes occurring and potential solutions to the dilemma.

EARTH COSTS OF ENERGY (to be revealed at end of activity):

Oil = ½ Earth per card	Power plant = 3 Earths per card
Wind Mill = ½ Earth per card	Renewable Energy = 1 Earth per card

SUNSHINE STATE STANDARDS:

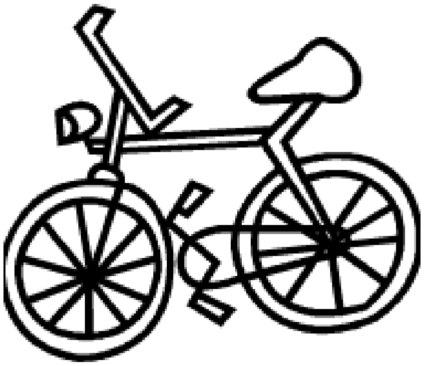
FL SC.G.2.3.1: The student knows that some resources are renewable and others are nonrenewable

FL SC.G.2.3.1.6.1: Student knows renewable and nonrenewable energy resources

FL SC.B.2.3.2: The student knows that most of the energy used today is derived from burning stored energy collected by organisms millions of years ago (e.g nonrenewable fossil fuels).

FL SC.B.2.3.2.7.1: The student knows that fossil fuels are found in the Earth, they are nonrenewable, and the advantages and disadvantages of their use.

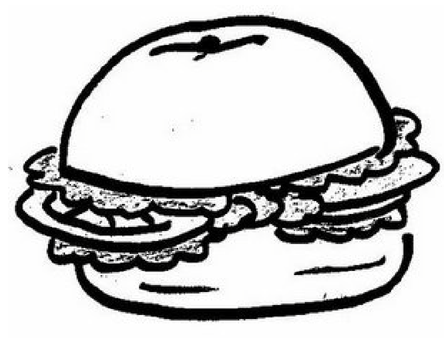
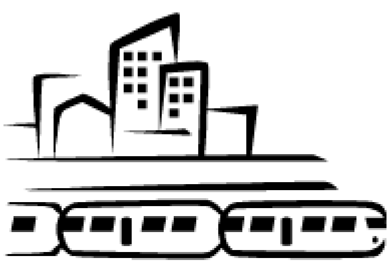
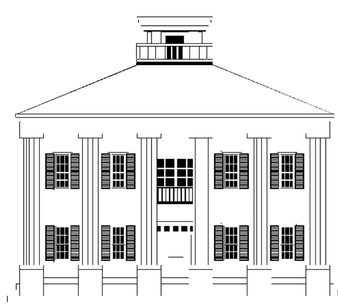
FL SC.B.1.3.1.8.2: The student knows examples of natural and man-made systems in which energy is transferred from one form to another



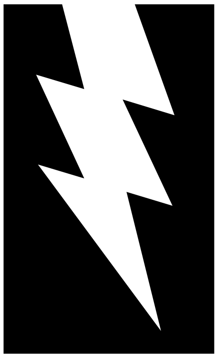
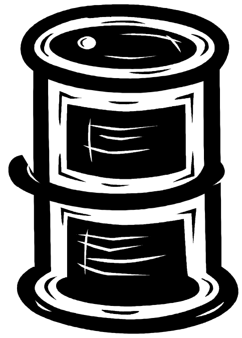
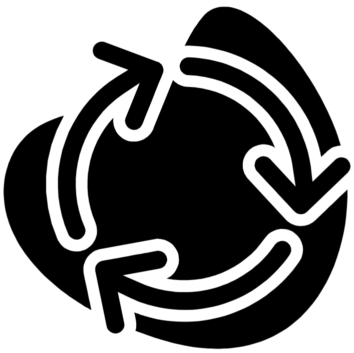
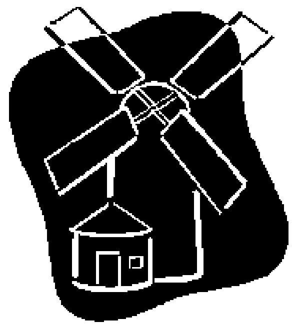







FOOD **Home Grown** **0 energy** • Same meals everyday • No snacks or deserts	HOUSING **Cabin** **10 electrical energy** • No running water • Wood burning heater • 2 electrical outlets	TRANSPORTATION **Bicycle** **0 energy** • Can't carry a lot • Mercy of the weather • Can't travel
FOOD **Locally Produced** **4 energy: electrical or oil** • Same meals each week • Rare snacks or deserts	HOUSING **Apartment** **20 electrical energy** • Noisy neighbors • No yard • 5 electrical outlets	TRANSPORTATION **Fuel-efficient Car** **7 oil energy** • Radio only • Only 1 passenger • Dented and rusted
FOOD **Name Brand** **6 electrical & 6 oil energy** • Your choice of meals everyday • Occasional snacks and deserts	HOUSING **House** **30 electrical energy** • Front yard • Pets Allowed • 10 electrical outlets	TRANSPORTATION **Tricked-out Truck** **11 oil energy** • TVs and Game system • Bring all your friends • Spinning rims
FOOD **Eat Out** **8 electrical & 8 oil energy** • Eat whatever you want, whenever you want	HOUSING **Mansion** **50 electrical energy** • Pool & Football field • Theatre Room • 100 electrical outlets	TRANSPORTATION **Public Transportation** **5 electrical energy** • Must follow schedule • Crowded & smelly • Dangerous at night

 COAL POWERPLANT • Provides 40 electrical energy	 OIL BARREL • Provides 10 oil energy
 RENEWABLE ENERGY • Provides 20 electrical energy	 WIND MILL ENERGY • Provides 10 electrical energy

ENTERTAINMENT **Over-seas Travel** **13 oil energy**	ENTERTAINMENT **Road Trips** **6 oil energy**	ENTERTAINMENT **Movies & Video Games** **7 electrical energy**
ENTERTAINMENT **Sports** **5 electrical energy**	ENTERTAINMENT **Reading** **0 energy**	ENTERTAINMENT **Cell Phone** **3 energy**

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Lesson 2: Creating Electricity

KEY QUESTIONS:
Where does electricity come from?
What is a generator, and how do they work?

SCIENCE SUBJECT: Physical Science

GRADE LEVEL: 6-8

SCIENCE CONCEPTS: Mechanical and electrical energy

TIME ESTIMATES: A 50-minute period

LEARNING STYLES: Visual, auditory and kinesthetic

VOCABULARY:
- Energy: the ability to do work or cause a change
- Electrical energy: the flow of electrical charge (electricity)
- Mechanical energy: energy that causes movement
- Energy conversion: changing one type f energy to another
- Generator: a device that converts mechanical energy to electrical energy
- Magnet: an object that produces a magnetic field and attracts or repels materials that are ferromagnetic (will interact with magnetic fields)
- Circuit: a network of two or more components creating a complete path of a electric current
- Current: the flow of electric charge
- Electromagnetic induction: the induction of an electromotive force by the motion of a conductor across a magnetic field or within a changing magnetic field

LESSON SUMMARY:

Where does electricity come from? Most middle-school students, and adults for that matter, would reply with, "the utility company." The process of producing electricity for use in homes is easily overlooked and taken for granted because of the convenience of electricity in our developed world. Developing an understanding of the process of creating electricity will give students an appreciation for electricity as a resource, not merely an ever-present luxury. In this lesson, students will build their own human powered generator, and in the process of doing so will understand principles of mechanical and electrical energy conversions, magnetism, and electricity (including simple circuits and current). Students will also gain an appreciation for how much mechanical energy is required to generate and sustain even the smallest amount of electricity.

STUDENT LEARNING OBJECTIVES:

After completing this lesson students should:

- Understand that electricity must be generated
- Understand how electricity is generated
- Understand the components of a simple circuit
- Appreciate the ability they have to create their own energy
- Propose ways their generator could be improved

MATERIALS:

ESSENTIAL:

The following materials are needed to build a single generator:

- 4 – 1x2x5cm ceramic magnet: Radio Shack #64-1877
- 1 - #30 Magnet wire 200ft: Radio Shack #278-1345
- 1 - Miniature Lamp, 1.5V 25mA: Radio Shack #272-1139
- 1 - Cardboard strip, 8cm x 30.4cm
- 1 - Large nail, 8cm long or more

SUPPLEMENTAL:

- Videos of the various human powered machines

BACKGROUND:

Electric generators are devices that convert mechanical energy into electrical energy through the process of electromagnetic induction. Generators cause electric charges to be moved through a circuit, and in doing so create electricity. Creating this electrical current does not create electrons, nor does it cause electrons to flow through the wires of the circuit. Rather, electrical current causes the *charge* of the electrons to be passed along the atoms within the wire. Many types of electric generators have been conceived, but each relies on the principle of moving a magnetic field relative to a conductor (or vice versa), which causes electromotive force, the driving force that produces electrical current.

For our electric generator, we will use the mechanical energy produced by our hand to spin magnets that will induce an electric current into a coil of wires, providing the electricity needed light a small light bulb. The spinning magnets cause moving magnetic fields, which try to create electric current through the wires surrounding the magnets. If the wires are in a closed circuit (a completed loop), then electric charges can be 'pumped' around the circuit, however if there is a break in the circuit (an open circuit) then the charges have nowhere to flow to and a voltage difference will appear at the end of the wires. In other words, electricity will only flow if it can flow in a continuous loop. However, a single loop of wire around a generator creates a small, insignificant amount of current, and only by using multiple coils of wire is any useful amount of voltage created. Each loop of wire works in series to create a coil that summates the voltage from each loop into a large, collective voltage. So by adding more coils of wire around a generator one can effectively increase the voltage output; the other way to achieve this is to increase the rate of the moving magnetic field. Even by using hundreds of loops of wire to create the coil for our generator, the voltage produced using the (relatively) small magnets is still very small, only around 2 volts. Luckily, the light bulb only requires 1.5 volts and we can supply the required mechanical energy from our hands with relative ease.

ADVANCE PREPARATION:

Organize materials so they are easily distributable as 'kits' to the individual student or groups.

PROCEDURE WITH TIME ESTIMATES:

Introduction and demonstration (10 minutes)

Introduce the concept of a generator and how it is used to generate electricity. Show optional videos of human-powered machines, noting the potential to make just about anything human-powered. Reveal and demonstrate the simple generator the students will be making.

Generator Construction (40 minutes)

Distribute materials to the students (depending on resources, students can build their own generator or work in groups up to three). Explain the stages of construction and reinforce the students to work together and ask questions when unsure. Small mistakes can cause the generators to malfunction, so it is essential that the procedure is followed accordingly.

CONSTRUCTION INSTRUCTIONS:

1. Make the hollow-ended box. Score the cardboard strip like so:

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 ____________________________________________________________________
|     8cm     | 3.5cm  |      8cm      | 3.2cm |     7.7cm    |
|             |        |               |       |              |
|             |        |               |       |              |
|             |        |               |       |              |
|8 cm         |        |               |       |              |
|             |        |               |       |              |
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|             |        |               |       |              |
|_____________|________|_______________|_______|______________|
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2. Fold the box as shown:

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   _____7.7_______
  _|______________ \
 |\     8      | \ 3.5
 | \3.2         |  \
 |  \_____________|___\
 |  |      8      |
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3. On the lonely 8 cm side, draw an ‘X’ from corner to corner to determine the exact center of the box.
4. Use a nail to poke a hole through the center of the side of the box and through the opposite side of the box, so the nail is passing through the box and sticking out from each side of the box. It will help with you use the nail to widen the holes a small amount so that it can spin freely but securely.

5. Next place your magnets, in two stacks of two magnets each, inside the box so the large faces 'clamp' around the nail. The magnets should be centered about the nail and within the box. It will take some adjusting (and possible use of spacers in the gaps between the two stacks of magnets) to get the magnets oriented correctly, but they are set when they spin with the nail and without scraping the sides of the box. It may help to use tape to secure the stacks of magnets to each other.
6. Next, take about 20 cm of one end of wire and tape it to the inside of the box, just to keep it secured and out of the way. Now coil the rest of the wire around the outside of the middle of box (keep your coil close to the center, where you have made your hole) so that your coils do not pass across the open ends of the box. It will take about 250 loops of the wire. Make sure not to wrap the wire so tightly that it begins to collapse the box from the tension.
7. Using the first end of wire that was taped inside the box and the other end of wire left after coiling, complete the circuit by attaching each wire of the light bulb to one of the coil ends. Ensure the connections are entirely wire-to-wire and there is no plastic insulation incorporated into your connections.
8. The generator should be operational at this point. Give the nail a spin to see if the magnets are spinning freely within the box; adjustments will be necessary with the magnets are not able to spin really FAST – make sure they are not scraping the edge of the box and there is no unnecessary resistance from the wire coils or nail-holes that is restricting their spinning. The magnets need to spin at least 8 revolutions per second in order to light the light bulb – but the faster the spinning, the brighter the light bulb will be!

SUNSHINE STATE STANDARDS

SC.2.P.10.1: Discuss that people use electricity or other forms of energy to cook their food, cool or warm their homes, and power their cars.

SC.5.P.11.1: Investigate and illustrate the fact that the flow of electricity requires a closed circuit (a complete loop).

SC.5.P.11.2: Identify and classify materials that conduct electricity and materials that do not.

SC.3.P.10.2: Recognize that energy has the ability to cause motion or create change.

SC.5.P.10.1: Investigate and describe some basic forms of energy, including light, heat, sound, electrical, chemical, and mechanical.

SC.5.P.10.4: Investigate and explain that electrical energy can be transformed into heat, light, and sound energy, as well as the energy of motion.

SC.7.P.11.2: Investigate and describe the transformation of energy from one form to another.

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Lesson 3: Energy Catapults

KEY QUESTIONS:

Can energy be stored?
What is the difference between potential and kinetic energy?

SCIENCE SUBJECT: Physical Science

GRADE LEVEL: 6-8

SCIENCE CONCEPTS: Mechanical energy

TIME ESTIMATES: 5-8 – 50-minute periods

LEARNING STYLES: Visual, auditory and kinesthetic

VOCABULARY:

- Catapult: a non-handheld device that is capable of launching a projectile without the use of explosives
- Potential energy: stored energy; the energy an object has due to its position, molecular arrangement, or chemical composition
- Kinetic energy: energy of motion; an object's speed is directly related to the amount of kinetic energy acting upon the object
- Mechanical energy; total kinetic and potential energy of an object
- Mechanical advantage: the amount a machine increases the input force into its output force
- Level: a rigid bar that rotates around a fixed point
- Fulcrum: a fixed point that a lever arm rotates about
- Leverage: a mechanical advantage gained by using a lever

LESSON SUMMARY:

Prior to the invention of explosives (i.e. gunpowder) long range warfare was constrained to artillery that were able to store and quickly release huge amounts of potential energy. These weapons took on many forms including: onager (the 'standard' catapult with a large lever arm with bucket), trebuchet (a lever arm with sling attached), and the ballista (essentially a giant crossbow). In this lesson students will explore concepts of potential and kinetic energy through designing, constructing, and testing an original catapult. Students will learn of various ways to store and release potential energy, and will develop an understanding of how kinetic energy creates movement. Students will compete in groups against each other to evaluate the effectiveness of their catapults.

STUDENT LEARNING OBJECTIVES:

After completing this lesson students should:

- Understand that potential energy can be converted to kinetic energy and that kinetic energy can be converted to potential energy
- Understand that potential energy is stored energy
- Understand that kinetic energy cause movement
- Appreciate the complexity of engineering new devices
- Practice the measurement and spatial skills necessary to design and build a structure out of a limited set of materials

MATERIALS:

ESSENTIAL:

- A limited amount of various building materials per group, such as:

2 x 4 – 1 meter
Nylon Rope – 1.5 meters
wooden dowels:
- small square – .45 m
- large square - .45 m
- small round - .4 m
- large round - .4 m

plywood – 30 cm x 60 cm piece
rubber bands – 10 (large)
metal washers – 4 (assorted sizes)
nails – as needed
screws – as needed
wood glue – as needed
super glue – as needed
duct tape – 2 meters

- A set projectile for each group (such as a can, a coin, a test tube stopper)

- Tools:
  - Circular saw
  - Jigsaw
  - 2 Sawhorses
  - Extension cord

- Drill and drill bits (sized according to the diameters of the dowels)
- Hammers
- Screwdrivers
- Sandpaper
- Hand clamps (assorted sizes)

- Safety Equipment:
    - Goggles
    - Gloves

SUPPLEMENTAL:
- Movies demonstrating how various types of catapults work

BACKGROUND:

All moving objects have energy. The energy that causes an object to move is called *kinetic energy*. Kinetic energy is produced when stored energy, called *potential energy*, is released. Potential energy can come from an objects position (usually utilizing the pull of gravity), molecular arrangement, or chemical composition. Potential energy is converted into kinetic energy when the stored energy is released, resulting in the movement of an object(s). Collectively, the amount of potential and kinetic energy an object has at any moment is called *mechanical energy*.

This lesson will use projectile launching catapults to illustrate the concept of potential and kinetic energy. All catapults rely on the release of potential energy, stored in various ways, to create focused kinetic energy that is transferred to a projectile. Catapults use mechanical advantage of simple machines, such as lever arms, to create great amounts of potential energy that can be released on a specific point. The potential energy typically utilized in catapult design comes from either gravity (whereby a large mass is raised in the air), or the elastic properties of the building materials (such as bending wood or stretching rope). In this activity, students should be encouraged to explore many different ways of creating potential energy with various building materials.

In designing a catapult, the efficiency of energy transfer, from potential energy to kinetic energy, will determine its effectiveness. By minimizing the energy lost from the catapult (due, for instance, to friction or stabilizing requirements) it is assured that maximum energy is transferred to the projectile. Furthermore, attempts to increase the mechanical advantage of components of the catapult will correspond to more efficient energy transfers, and thus more effective catapults.

ADVANCE PREPARATION:

Organize materials so they are easily distributable as sets to the groups.

PROCEDURE WITH TIME ESTIMATES:

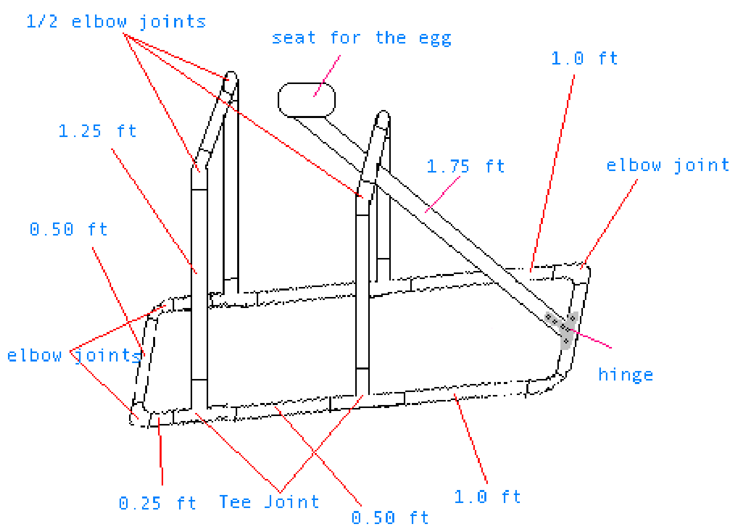
Introduction (10 minutes)

Discuss how modern weapons fire projectiles using explosives that cause chemical reactions that release large amounts of energy. Introduce the concept of catapults as devices that launch projectiles without the use of explosives, only stored energy. Show optional videos of catapults.

Design (2 days)

Give the students their supplies list and instruct them to design a *detailed* blueprint of their catapult; have students include drawings of multiple viewpoints, materials labeled, and measurements listed. Since limited materials are available, careful planning is necessary to ensure supplies do not run out. Upon approval of design, students can be given materials and the consent to begin construction. Since many students may be intimidated by having to draw detailed plans, it may be beneficial to show students examples of simple 2 dimensional drawings (see below) to show them how to incorporate material labels and estimated measurements.

NOTE: drawing is not drawn to scale...



Construction (2-4 days)

Students will follow their blueprint and construct their catapult out of the given supplies. The instructor should perform all tasks that require power tools, such as cutting or drilling. It works well to have students measure and draw on the materials where they would like a cut or hole and then bring the ready materials to a designated cutting/drilling station. Reinforce proper safety procedures constantly by modeling safe behavior yourself!

Testing and Discussion (1-2 days)

Before going outside to test the catapults, have a discussion about what criteria they think make a successful catapult. Encourage the students to use the correct scientific vocabulary in their explanations. Students should be able to articulate that the catapult can store and convert the most potential energy to kinetic energy should win. Have students hypothesize which catapult in the class will win and why (scientifically) they feel that way.

Have groups compete in a launching competition that includes a maximum distance event and an accuracy event. In the distance event, maximum distance of projectile should be measured repeatedly and an average calculated. The accuracy event could include a target marked out in a field with each smaller ring of the target worth increasing points; three trials could be attempted and a total score for all three shots tabulated. A discussion should follow recognizing why certain designs were effective and why other designs failed. Have students reexamine their hypotheses and explain why they may have been right or wrong.

SUNSHINE STATE STANDARDS:

1) SC.6.P.11.1: Explore the Law of Conservation of Energy by differentiating between potential and kinetic energy. Identify situations where kinetic energy is transformed into potential energy and vice versa

2) SC.7.P.11.2: Investigate and describe the transformation of energy from one form to another.