TURNING IDEAS INTO REALITY:
ENGINEERING A BETTER WORLD
The Zip Line

Targeted Grades
3 – 8

STEM Career Connections
Transportation, Distribution & Logistics
Human Services
Civil Engineering
Mechanical Engineering

STEM Disciplines
Science
Technology
Engineering

Non-STEM Discipline
English Language Arts

Academic Content Standards

Ohio's New Learning Standards: Science Cognitive Demands
Expectations for Learning Cognitive Demands K-12 **Designing Technological / Engineering Solutions Using Science Concepts:** Requires student to solve science-based engineering or technological problems through application of scientific inquiry. Within given scientific constraints, propose or critique solutions, analyze and interpret technological and engineering problems, use science principles to anticipate effects of technological or engineering design, find solutions using science and engineering or technology, consider consequences and alternatives, and/or integrate and synthesize scientific information. **Demonstrating Science Knowledge:** Requires student to use scientific inquiry and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigations, using appropriate tools and techniques to gather and organize data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments. **Interpreting and Communication Science Concepts:** Requires student to use subject-specific conceptual knowledge to interpret and explain events, phenomena, concepts and experiences using grade-appropriate scientific terminology, technological knowledge and mathematical knowledge. Communicate with clarity, focus and organization using rich, investigative scenarios, real-world data and valid scientific information.

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Expectations for Technology and Engineering Design: Guiding Principles Grades PreK-8

Technological Design:

Technological design is a problem or project-based way of applying creativity, science, engineering and mathematics to meet a human need or want. Modern science is an integrated endeavor. Technological design integrates learning by using science, technology, engineering and mathematics and fosters 21st Century Skills.

Technology and Engineering:

Technology modifies the natural world through innovative processes, systems, structures and devices to extend human abilities. Engineering is design under constraint that develops and applies technology to satisfy human needs and wants. Technology and engineering, coupled with the knowledge and methods derived from science and mathematics, profoundly influence the quality of life.

Examples of the grade-appropriate skills expected of students:

PreK-4:

- Identify problems and potential technological/engineering solutions
- Understand the design process, role of troubleshooting
- Understand goals of physical, informational and bio-related technologies
- Understand how physical technologies impact humans

Grades 5-8:

- Understand and be able to select and use physical and informational technologies
- Understand how all technologies have changed over time
- Recognize role of design and testing in the design process
- Apply research, innovation and invention to problem solving

Ohio's New Learning Standards: Science Guiding Principles Grades 3-8

There is no science without inquiry. Scientific inquiry is a way of knowing and a process of doing science. It is the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Scientific inquiry also refers to the activities through which students develop knowledge and understanding of scientific ideas as well as an understanding of how scientists study the natural world.
Teachers need to model scientific inquiry by teaching with inquiry.

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Grades 3-5:
During the years of PreK-4, all students must become proficient in the use of the following scientific processes, with appropriate laboratory safety techniques, to construct their knowledge and understanding in all science content areas:

- Observe and ask questions about the natural environment;
- Plan and conduct simple investigations;
- Employ simple equipment and tools to gather data and extend the senses;
- Use appropriate mathematics with data to construct reasonable explanations;
- Communicate about observations, investigations and explanations; and
- Review and ask questions about the observations and explanations of others.

Theme: Interconnections within Systems

This theme focuses on helping students explore the components of various systems and then investigate dynamic and sustainable relationships within systems using scientific inquiry.

Grades 6-8:
During the years of grades 5-8, all students must use the following scientific processes, with appropriate laboratory safety techniques, to construct their knowledge and understanding in all science content areas:

- Identify questions that can be answered through scientific investigations;
- Design and conduct a scientific investigation;
- Use appropriate mathematics, tools and techniques to gather data and information;
- Analyze and interpret data;
- Develop descriptions, models, explanations and predictions;
- Think critically and logically to connect evidence and explanations;
- Recognize and analyze alternative explanations and predictions; and
- Communicate scientific procedures and explanations.

Theme: Order and Organization

This theme focuses on helping students use scientific inquiry to discover patterns, trends, structures and relationships that may be described by simple principles. These principles are related to the properties or interactions within and between systems.

Ohio's New Learning Standards: Physical Science Grades 3-8

Grade 3: Matter and Forms of Energy

Content Statement: Heat, electrical energy, light, sound and magnetic energy are forms of energy.
There are many different forms of energy. Energy is the ability to cause motion or create change.
Note: The different forms of energy that are outlined at this grade level should be limited to familiar forms of energy that a student is able to observe.
Content Elaboration:
Examples of energy causing motion or creating change include a falling rock causing a crater to form on the ground, heating water causing water to change into a gas, light energy from the sun contributing to plant growth, electricity causing the blades of a fan to move, electrically charged objects causing movement in uncharged objects or other electrically charged objects, sound from a drum causing rice sitting on the drum to vibrate, and magnets causing other magnets and some metal objects to move.
Investigations (3-D or virtual) must be used to demonstrate the relationship between different forms of energy and motion.
Note 1: It is not appropriate at this grade level to explore the different types of energy in depth or use wave terminology when discussing energy. These will be developed at later grades.
Note 2: There often is confusion between the concepts of force and energy. Force can be thought of as a push or pull between two objects and energy as the property of an object that can cause change. If forces actually push or pull something over a distance, then there is an exchange of energy between

Grade 4: Heat, Electricity and Matter

Content Statement:
Energy can be transformed from one form to another or can be transferred from one location to another.
Content Elaboration:
Note 4: Energy transfer (between objects or places) should not be confused with energy transformation from one form of energy to another (e.g., electrical energy to light energy).

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Grade 5: Light, Sound and Motion

Content Statement:

The amount of change in movement of an object is based on the mass* of the object and the amount of force exerted.

Movement can be measured by speed. The speed of an object is calculated by determining the distance (d) traveled in a period of time (t).

Earth pulls down on all objects with a gravitational force. Weight is a measure of the gravitational force between an object and the Earth.

Any change in speed or direction of an object requires a force and is affected by the mass* of the object and the amount of force applied.

Content Elaboration:

The motion of an object can change by speeding up, slowing down or changing direction. Forces cause changes in motion. If a force is applied in the same direction of an object's motion, the speed will increase. If a force is applied in the opposite direction of an object's motion, the speed will decrease. Generally, the greater the force acting on an object, the greater the change in motion. Generally, the more mass* an object has, the less influence a given force will have on its motion. If no forces act on an object, the object does not change its motion and moves at constant speed in a given direction. If an object is not moving and no force acts on it, the object will remain at rest.

Movement is measured by speed (how fast or slow the movement is). Speed is measured by time and distance traveled (how long it took the object to go a specific distance). Speed is calculated by dividing distance by time. Speed must be investigated through testing and experimentation. Real-world settings are recommended for the investigations when possible.

An object that moves with constant speed travels the same distance in each successive unit of time. In the same amount of time, a faster object moves a greater distance than a slower object. When an object is speeding up, the distance it travels increases with each successive unit of time. When an object is slowing down, the distance it travels decreases with each successive unit of time.

**While mass is the scientifically correct term to use in this context, the NAEP 2009 Science Framework (page 27) recommends using the more familiar term "weight" in the elementary grades with the distinction between mass and weight being introduced at the middle school level.*

Grade 6: Matter and Motion

Content Statement:

There are two categories of energy: kinetic and potential.

Objects and substances in motion have kinetic energy.

Objects and substances can have energy as a result of their position (potential energy).

Content Elaboration:

There are many forms of energy, but all can be put into two categories: kinetic and potential. Kinetic energy is associated with the motion of an object. The kinetic energy of an object changes when its speed changes. Potential energy is the energy of position between two interacting objects. Gravitational potential energy is associated with the height of an object above a reference position. The gravitational potential energy of an object changes as its height above the reference changes.

Note: Using the word "stored" to define potential energy is misleading. The word "stored" implies that the energy is kept by the object and not given away to another object. Therefore, kinetic energy also can be classified as "stored" energy. A rocket moving at constant speed through empty space has kinetic energy and is not transferring any of this energy to another object.

Grade 7: Conservation of Mass and Energy

Content Statement:

Energy can be transferred through a variety of ways.

Mechanical energy can be transferred when objects push or pull on each other over a distance.

Content Elaboration:

Mechanical energy is transferred when a force acts between objects that move one of the objects some distance with or against the force. The amount of energy transferred increases as the strength of the force and/or the distance covered by object increases. This energy transfer (work) stops when the objects no longer exert forces on each other.

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Grade 8: Conservation of Mass and Energy

Content Statement:

Energy can be transferred through a variety of ways.

Mechanical energy can be transferred when objects push or pull on each other over a distance.

Content Elaboration:

Mechanical energy is transferred when a force acts between objects that move one of the objects some distance with or against the force. The amount of energy transferred increases as the strength of the force and/or the distance covered by object increases. This energy transfer (work) stops when the objects no longer exert forces on each other.

Content Statement:

There are different types of potential energy.

Gravitational potential energy changes in a system as the masses or relative positions of objects are changed. Objects can have elastic potential energy due to their compression or chemical potential energy due to the nature and arrangement of the atoms that make up the object.

Content Elaboration:

Gravitational potential energy is associated with the mass of an object and its height above a reference point (e.g., above ground level, above floor level). A change in the height of an object is evidence that the gravitational potential energy has changed.

Elastic potential energy is associated with how much an elastic object has been stretched or compressed and how difficult such a compression or stretch is. A change in the amount of compression or stretch of an elastic object is evidence that the elastic potential energy has changed.

The different types of potential energy must be explored through experimentation and investigation that include the relationship of energy transfer and springs, magnets or static electricity.

Learning Experience Overview

Essential Question

How can a zip line and cable car wires be used to design a contraption capable of moving inhabitants of an island to neighboring cities?

Enduring Understandings

- The use of collaboration and the engineering design process are both important, and help to creatively design effective solutions to problems.

Design Challenge Problem/Scenario

A recent earthquake has collapsed a bridge, which was the only way out of an island. The islanders are running out of resources quickly, and need help. Your engineering team has concluded that the best and safest option is to transport the people off the island. The water's current is currently too strong, making it an unsafe means of transportation. The only means of transportation remaining is the island's famous zip line, which includes a section leading from the island to a neighboring city.

Engineering Design Challenge

Your team's challenge is to design and build a cradle that will safely transport one islander at a

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time across the zip line from the island to the neighboring city.

Prerequisite Knowledge & Skill (as connected to academic content standards)

- **Concepts Related to Energy in Grades PreK-2:** A variety of sounds and motions are experienced. The sun is the principle source of energy.

Activity Timeframe and Overview *(50 minutes)*

Activity	Time	Overview
Introduction	*2 minutes*	Introduce Yourself Provide Brief Activity Overview to Foster Excitement
Pre-Assessment	*3 minutes*	Administer Kit's Pre-Activity Survey
Design Challenge Introduction	*10 minutes*	Begin PowerPoint Presentation: ● Guide Discussion and Show Video - **must be ended abruptly at 1m14s** ● Present the Engineering Design Challenge ● Explain the Engineering Design Process
Individual Brainstorm	*2 minutes*	Team Members Individually: ● Write Solution Ideas on Post-It Notes
Prototype Design and Construction	*15 minutes*	Teams Collaboratively: ● Discuss Individual Ideas ● Choose and Sketch Final Idea for Approval ● Gather Materials and Construct Team Prototype
Testing	*10 minutes*	Perform and Observe Prototype Testing
Conclusion	*5 minutes*	Relate to Engineering; They Did What Engineers Do Connect to Types of Engineering
Post-Assessment	*3 minutes*	Administer Kit's Post-Activity Survey

Material List

Material	Quantity per Team	✓	Quantity per Kit	✓
Straws	5		50	
Masking Tape	3 in		1 roll	
String *(for team designs & for 1 zip line used to test designs)*	1 foot *(per team)* 4 feet *(for zip line)*		1 roll	
Toothpicks	8		60 count box	

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Duct Tape	2 inch		1 roll	
Paperclips	3		30 count box	
Pipe Cleaners	2		40 count bag	
Wooden Craft Sticks	4		140 count box	
Ribbon	5 inches		3 yd roll	
Rubber Bands	5		150 count bag	
Cups	1		35	
Lego People	1		5	
Scissors *(to cut duct tape)*	~		1	
Memory Stick *(With power point and handouts)*	~		1	
Pre-Activity Survey	~		25 copies	
Post-Activity Survey	~		25 copies	
Cardstock	1 sheet		1 pack	
Paper *(For individual brainstorming)*	1 sheet		25 sheets	
Paper *(For team design sketch)*	1 sheet		15 sheets	

Instruction

Prior to Lesson Delivery

- Set up the zip line for testing.

  Set-up the zip line so that it is:
  - On a steep slope.
  - 3 – 4 feet in length.
  - Taught, with no slacking or sagging.
- Test the zip line's length and slope; making sure it is efficient for student test use.

Instructional Sequence

Note: The activity's PowerPoint presentation guides instruction and visually presents information to students. Therefore, the instructions include corresponding slide numbers.

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1. Slide 1: As the pre-activity survey is distributed to students, introduce yourself and provide enough of an activity overview to gain students excitement.
2. Allow time for students to individually complete their pre-activity survey.
3. Divide group into teams of 3 to 4 students each.
4. Slides 2 and 3: Discuss engineering and what engineers do.
5. Present the engineering design problem and challenge, following the presentation:
   - Slide 4: Show "Zipline Rescues from Mexico Floods" video –

     NOTE: Video must be ended abruptly at 1m14s.

   - Slide 5: Present the real-world engineering design problem (scenario).
   - Slide 6: Introduce the Engineering Design Challenge.
   - Slide 7: Discuss Engineering Design Goals.
   - Slide 8: Introduce resources (materials) available to each team.
   - Slide 9: Explain prototype-testing procedures.
6. Slide 10: Introduce the Engineering Design Process. Explain that engineers use it as a tool to help them more effectively solve problems.
7. Slide 11: Explain how teams will use the engineering design process as they complete the challenge:

   Imagine *(10 min.)*
   - INDIVIDUALLY: observe available materials, and brainstorm and write design ideas *(5 min.)*
   - TEAM: share individual ideas *(5 min.)*

   Plan *(5 min.)*
   - Choose and sketch a team design plan

   Create *(10 min.)*
   - Gather materials
   - Construct your team design plan

   Improve and Test *(10 min.)*
   - Teams decide on and make any last minute improvements before testing
   - Each team tests their prototype while other teams observe
   - Start with only one push from the top of the zip line
   - Ensure the zip line has a steep slope
   - Design must make it to the bottom of the zip line, holding Lego people throughout
8. Slide 12: Facilitate a whole group reflection on final prototype design and testing results by asking questions such as the following.
   - What do you like best about your design?
   - What do you like least about your design?
   - What aspects of other team designs stood out to you, and/or gave you ideas for improving your own team's design?
   - What modifications would you make if we had time to complete the design challenge

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again?
    - Do you think that changing the slope (angle) of the zip line would make a difference?
    - How did transformations between potential energy and kinetic energy force your design to move along the zip line?
    - What role did friction play on the safety and speed of your design as people were transported along the zip line?
9. Slide 13: Conclude by discussing the following questions as post-activity surveys are distributed.
    - What ideas do you have for engineering a better world?
    - How can you turn ideas into reality?
10. Slide 14: Allow time for students to complete their post-activity survey.

STEM Career Connections

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Human Services
Civil Engineering
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Assessments

- Pre-Activity Survey
- Post-Activity Survey

References

This activity has been adapted from the Rescue Rover and Conveyor Belt activities provided from tryengineering.com.

Conveyor Engineering - http://www.tryengineering.org/lesson-plans/conveyor-engineering

Rescue Rover - http://www.tryengineering.org/lesson-plans/rescue-rover

Zipline rescues from Mexico floods. *NBCNews.com*. NBC nightly news, 18 Sept 2013. Retrieved from: http://www.nbcnews.com/video/nightly-news/53044233#53044233.

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NBC Nightly News

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Smooth Operator Presentation by Margaret Pinnell, PhD.

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