TURNING IDEAS INTO REALITY:
ENGINEERING A BETTER WORLD

The Cracker Catapult

Targeted Grades
4, 5, 6, 7, 8

STEM Careers
Mechanical Engineering
Civil Engineering
Architecture
Construction

STEM Disciplines
Science
Technology
Engineering

STEM Disciplines
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.
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

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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.

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 6-8

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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).

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.

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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.

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.

Ohio's New Learning Standards: English Language Arts
College and Career Readiness Anchor Standards Grades K-12

Speaking and Listening

Comprehension and Collaboration:

- Prepare for and participate effectively in a range of conversations and collaborations with diverse partners, building on others' ideas and expressing their own clearly and persuasively.
- Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.
- Evaluate a speaker's point of view, reasoning, and use of evidence and rhetoric.

Presentation of Knowledge and Ideas:

- Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.

Language

Vocabulary Acquisition and Use:

- Acquire and use accurately a range of general academic and domain-specific words and phrases sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

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Learning Experience Overview

Essential Question
How can materials be used to lower the force of impact and protect fragile objects?

Enduring Understandings
- Using the engineering design process when approaching problems results in unique solutions.
- Increasing the strength of a force applied to an object will increase the amount of kinetic energy transferred to the object; the object's speed and distance travelled also increases.
- Increasing the speed an object travels also increases the force of impact the object experiences as its kinetic energy is stopped suddenly by an opposing force (such as the ground).

Design Challenge Problem/Scenario
An earthquake in Hawaii has collapsed the only bridge leading into or out of a town. The town's people are stuck, and in need of supplies! In order to transport supplies over the collapsed bridge, the neighboring town built a catapult and is flinging materials from one side to the other! A great amount of force is being applied to the materials in order to transfer enough kinetic energy and speed for them to make to the other side. Many supplies are being damaged because their high speeds and amount of kinetic energy causes them to hit the ground with great force. The town's people are trying to solve this problem by designing a way to protect supplies from being damaged as they are sent to the town in need.

Engineering Design Challenge
Your team's challenge is design a way to safely transfer the potential energy in the catapult to kinetic energy in the crackers without crackers breaking upon impact. Your design can include only the materials provided.
Note: For older students, an additional requirement can be added: The team that uses the least materials and ends with the most unbroken crackers wins the design challenge.

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.
- **Concepts Related to Energy in Grade 3:** Objects with energy have the ability to cause change. Heat, electrical energy, light, sound and magnetic energy are forms of energy.

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Activity Timeframe and Overview *(60 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 (1m, 12s) ● Present the Engineering Design Challenge ● Explain the Engineering Design Process
Build a Catapult	*7 minutes*	● Give Teams Craft Sticks and 3 Rubber Bands ● Play the Instructional Video ● Build Catapults
Individual Brainstorm	*2 minutes*	Team Members Individually: ● Write Solution Ideas on Post-It Notes
Prototype Design and Construction	*20 minutes*	Teams Collaboratively: ● Discuss Individual Ideas ● Choose and Sketch Final Idea for Approval ● Gather Materials and Construct Team Prototype
Testing	*8 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	✓
Craft Sticks *(standard-size)*	8		104	
Craft Sticks *(jumbo-size)*	2		26	
Cotton Balls	2		26	
Tissues	2		26	
Cracker Packets *(Individually wrapped)*	1 packet		13 packets *(Individually wrapped)*	
Coffee Filters	1		13	
String	1 foot		13 feet	
Scotch Tape	4 inches		72 inches	
Rubber Bands	5 *(Catapult-3 / design-2)*		65	

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(For catapult and design)				
Catapult *(For testing)*	~		1	
Memory Stick *(With power point and handouts)*	~		1	
Pre-Activity Survey	1 copy *(per student)*		25 copies	
Post-Activity Survey	1 copy *(per student)*		25 copies	
Paper *(For brainstorming)*	6 sheets		80 sheets	

Instruction

Instructional Sequence

Note: The activity's PowerPoint presentation guides instruction and visually presents information to students. Therefore, the instructions include corresponding slide numbers.
<u>Prep Work:</u> Separate the materials into the right amounts per group.

1. <u>Slide 1:</u> 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 2 to 4 students.
4. <u>Slides 2 and 3:</u> Discuss engineering and what engineers do.
5. Present the engineering design problem and challenge, following presentation:
    - <u>Slide 4:</u> Play video (1m, 12s).
    - <u>Slide 5:</u> Present the real-world engineering design problem (scenario).
    - <u>Slide 6:</u> Introduce the Engineering Design Challenge, stressing that each team will only receive on packet of crackers and they have to be careful not to break them.
    - <u>Slide 7:</u> Play the video (2m19s), and have teams follow instructions to quickly build a catapult.
    - <u>Slide 8:</u> Display the visual instructions for building a catapult as teams finish their catapults.
    - <u>Slide 9:</u> Share Engineering Design Goals.
    - <u>Slide 10:</u> Introduce resources (materials) available to each team.
    - <u>Slide 11:</u> Explain prototype-testing procedures.
6. <u>Slide 12:</u> Introduce the Engineering Design Process. Explain that engineers use it as a tool to help them more effectively solve problems.
7. <u>Slide 13:</u> 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.)*

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- 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.
  If the crackers do not break on the first round, elevate the catapult and do a round two if time permits! This time the catapult should be placed on a table in a position where the cracker will be launched off the table to the floor (at least a 3 foot drop).

8. Slide 14: 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 again?
9. Slide 15: 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. Allow time for students to complete their post-activity survey.

STEM Career Connections

STEM Career Connection:

- **Mechanical Engineering**
  The branch of engineering that involves the design, production, and operation of machinery and tools. It is one of the oldest and broadest of the engineering disciplines.
- **Civil Engineering**
  A professional engineering discipline that deals with design, construction, and maintenance of the physically and naturally built environment. Examples include works like roads, bridges, canals, dams, and buildings.

Technical Brief:

The concepts of kinetic and potential energy are important for this problem. The challenge is design a way to safely transfer the potential energy in the catapult to kinetic energy in the crackers without crackers breaking upon impact.

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References

Ohio's new learning standards. *Ohio department of education*. 08 Aug 2014. Retrieved from: http://education.ohio.gov/Topics/Ohio-s-New-Learning-Standards/Ohios-New-Learning-Standards.

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