Energy at Play

Design Challenge Learning

The Tech
Museum of Innovation

201 S. Market St.
San Jose, CA 95113
1-408-294-8324
thetech.org

Energize your students with this exploration of the way energy transforms and transfers. Using household items and their knowledge, students will build fun contraptions that will make a ball move and hit a target. As students iterate through this design challenge, they gain firsthand experience in the design process.

Grades 3-6

Estimated time: 60-90 minutes

<u>Student Outcomes:</u>

1. Students will be able to design and build a device that uses different forms of potential energy and kinetic energy to launch a ball towards a target.
2. Students will be able to explain design considerations based on concepts of energy and force.
3. Students will be able to utilize the three step design process to meet an engineering challenge.

<u>Next Generation Science Standards</u>

Grade 3-5: *Engineering Design* 3-5-ETS1-1, 3-5-ETS1-2, 3-5-ETS1-3
Grade 3: *Physical Science* 3-PS2-1, 3- PS2-2
Grade 4: *Physical Science* 4-PS3-1, 4-PS3-4
Grade 5: *Physical Science* 5-PS2-1
Grade 6: *Engineering Design* MS-ETS1-1, MS-ETS1-2, MS-ETS1-3, MS-ETS1-4

<u>Common Core Language Arts-Speaking and Listening</u>

Grade 3: SL.3.1b-d, SL.3.3, SL.3.4a
Grade 4: SL.4.1b-d, SL.4.4a
Grade 5: SL.5.1b-d, SL.5.4
Grade 6: SL.6.1b-d

<u>California Science Content</u>

Grade 3: *Physical Science* 1.b-d; *Investigation and Experimentation* 5.a-b, d
Grade 4: *Investigation and Experimentation* 6.a, 6.c-d
Grade 5: *Investigation and Experimentation* 6.a-c, 6.h
Grade 6: *Investigation and Experimentation* 7.a-b, 7.d-e

<u>Vocabulary:</u>

Familiarity with these terms and concepts will enhance students' experience in the activity

- <u>Conservation of Energy:</u> Energy cannot be created or destroyed; it may be transformed from one form into another, or transferred from one place to another, but the total amount of energy never changes.
- <u>Energy:</u> The capacity to do work. Appears in many forms, all of which are either kinetic or potential.
- <u>Gravitational Potential Energy:</u> Potential energy due to elevated position. *Note: This only depends on vertical displacement and not the path taken to get it there. This value is always relative to some reference level.*
- <u>Elastic Potential Energy:</u> Potential energy due to tension – either stretch (rubber bands, etc.) or compression (springs, etc.).
- <u>Force:</u> A push or a pull. An influence on a body or system, causing or tending to cause a change in movement or shape.
- <u>Kinetic Energy (KE):</u> Energy of motion. Includes heat, sound, and light (motion of molecules).

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- Mechanical Energy: Energy possessed by an object due to its motion or its stored energy of position. Mechanical energy can be either kinetic energy (energy of motion) or potential energy (stored energy of position).
- Potential Energy (PE): Energy of position; energy that is stored and held in readiness. Includes chemical energy, such as fossil fuels, electric batteries, and the food we eat.
- Work: A force acting on an object to move it across a distance. Pushing, pulling, and lifting are common forms of work.

Resources:

- PBS Learning Media: A great online resource for teachers powered by PBS. It contains videos, simulations, online games, lesson plans, projects, and background information and documents pertaining to a wide range of topics. The search feature will allow you to search “Kinetic Energy” or “Potential Energy” to pull up resources by grade. www.pbslearningmedia.org

- PhET Interactive Simulations: Administered by the University of Colorado Boulder, the website provides a variety of interactive simulations for science and math. It includes simulations dealing with motion, energy, power, and work. https://phet.colorado.edu

- Newton’s Cradle: An online interactive animation of Newton’s Cradle created by Bryan Heisey and administered by Lock Haven University. www.lhup.edu/~dsimanek/scenario/newton.htm

- Rube Goldberg: The official website for Rube Goldberg providing biographical information on the artist/engineer, his awards, career highlights, history, and legacy. www.rube-goldberg.com

- Real World Physics Problems: The website provides links for the history, design, and physics of catapults and trebuchets. www.real-world-physics-problems.com/physics-of-battle.html

- The Treb Challenge: Powered by GlobalSpec, this simulator/interactive game allows engineers to manipulate mass, angle, height, gravity, and wind to build and test a trebuchet. The three design challenges of distance, accuracy, and power make students reconsider design choices. At the end of each challenge physics and engineering facts are presented. The website is also a great resource for general engineering related information and research. www.globalspec.com/trebuchet

- Rolling Ball Sculptures: An Australian based artist, David Morrell combines science, engineering, and art in order to create interactive wire sculptures that transform gravitational potential energy to kinetic energy in different ways. A great source of inspiration for students. www.rollingballsculpure.com/au

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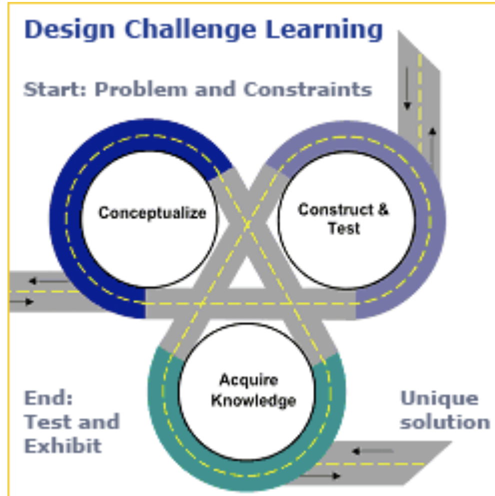
Design Challenge Process:

The Design Challenge Process is designed so students reinforce their science, mathematics, social studies, and language arts content knowledge, through an open-ended process that results in an original, team-driven solution. Students are expected to take responsibility for assessing their own progress and incorporate peer feedback as they conceptualize and redesign their projects.



The process consists of three interconnected steps:

Conceptualize
- Identify problem, materials, and constraints
- Brainstorm ideas and possible solutions

Construct and Test
- Select a solution
- Design and construct
- Prototype
- Redesign or modify
- Retest

Acquire Knowledge
- Research
- Share solutions
- Reflect and discuss

Through the try, fail, learn approach, students develop skills and habits of mind of Silicon Valley innovators: creativity, problem solving, design, collaboration, leadership, risk-taking, perseverance, and learning from failure.

Materials:

Materials can be limiting or inspirational to students! Have a wide variety of materials to promote a diversity of solutions. "Recycled items" are really useful: old mouse pads, wood scraps, boxes, cardboard tubes, strawberry baskets, etc.

Class Supplies to Share:
- Balloons
- Rubber Bands
- Paper Cups
- Tongue Depressors
- String
- Tape
- Drinking Straws
- Pipe Cleaners
- Cardboard
- Cardstock
- Plastic Spoons
- Springs
- Binder Clips
- Craft Sticks

Testing Supplies:
- Velcro Target (plate with Velcro strips)
- Velcro Balls (ping pong balls with Velcro strips)
- Taped-off Launching Area

Directed Instruction
- Newton's Cradle
- Spring-driven Top
- Spring-loaded Frisbee Gun
- Ball on an Elastic Band
- Bouncy Ball
- Slinky
- Rubber Popper
- Magnetic Gyro Wheel
- Wind-up Animal/Car
- Toy Catapult

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Lesson Plan:

Introduction *(5 minutes)*

1. This class is all about playing with energy. Think about things you use in your everyday life that use energy. Perhaps a toy that uses stored energy and then leaps into motion (wind-up toy, spring loaded top, or popper).
2. Sometimes we can use our own force to store energy (sling shot). Or we can use gravity to store energy for us (bouncy ball).
3. One of the most popular exhibits at The Tech Museum of Innovation in San Jose, CA is the "Ball Machine" that sends balls rolling down hills, spiraling through tracks, flying through the air, and bouncing across obstacles. Can you create a mini version of this machine?

Part I: Energy at Play Challenge *(20 minutes)*

1. Introduce the Challenge: Design and build a simple toy with its own propulsion mechanism that will move a ball at least 5 inches (without using your energy to directly move it).
2. Introduce the Constraints:
   - Your ball must move at least 5 inches, without using your energy to directly move it.
   - Your toy must store and transform energy in some way to move your ball.
   - You can only use the materials provided.
   - Each group member must participate in the design, construction, and operation of the toy.
   - You will be allowed to test your toy as you work.
3. Build: Give students about 10 minutes to build. Instructor should ask open-ended questions to help guide students through the design process, but should also allow students space to tinker. Testing during this build period should be encouraged.
4. Demonstration: Have students demonstrate their device for the class. If students have not completed their device, or their device did not function as expected, ask them *how the device would have worked.*
5. Reflection: Have each group of students explain their design strategy and how their device uses energy, force, and motion. The instructor should ask leading questions to get at the science behind the designs.
   - Teaching Points:
     - Energy comes in many forms and can be changed from one form to another.
     - Kinetic energy is the energy of motion and potential energy is the stored energy of position.
     - A force is a push or a pull. An object can have two or more forces that act on a single object including: gravity, elastic forces due to tension or compression, and friction.
   - Questions:
     - How is the energy stored in your toy?
     - How is the energy transferred in your toy?
     - Do you know what names scientists give to these different forms of energy? *Note: Potential Energy (PE) is stored energy. Kinetic Energy (KE) is the energy of motion.*
     - Do you know what types of Potential Energy are being demonstrated? *Note: PE can be either gravitational or elastic. Continue to identify the PE and KE of the various toys and form of PE being used.*

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Directed Instruction *(10 minutes)*

1. Teaching points:
    - Potential Energy is Stored Energy
    - Kinetic Energy is Energy of Motion
    - Potential Energy can be either Gravitational or Elastic
2. Law of Conservation of Energy: The total amount of energy in a system remains constant ("is conserved"), although energy within the system can be changed from one form to another or transferred from one object to another. Energy cannot be created or destroyed, but it can be transformed.
    - Demonstration Ideas:
        - Utilize Newton's Cradle to demonstrate how gravitational potential energy can become kinetic energy and that kinetic energy can be transferred to another object. Instructor should ask leading questions to get at the science behind the cradle. Students can interact with an online simulator found at: www.lhup.edu/~dsimanek/scenario/newton.htm
    - Questions:
        - How does this work?
        - Does the energy transfer?
        - Does the energy transform/change?
        - Why does it slow down?
        - Where does the energy go?
3. Research Stations: Introduce various toys that students can use to do research. Make sure to have a good variety of toys that demonstrate gravitational potential energy (e.g. yo-yo, magic wheel, bouncy ball), elastic potential energy (e.g. wind-up toys, sling shots), and both gravitational and elastic potential energy (e.g. slinky). Also make sure that you have toys that transfer energy to another object (e.g. catapult, slingshot).
    - Demonstration: Instructor should ask leading questions about the toys and the different types of energy they use. Have the students describe how the toy works while the instructor demonstrates.
    - Questions:
        - What type of potential energy does this toy store?
        - Does this toy transform energy? When? How?
        - Do any of these toys transfer energy to another object? Which ones?

Part II: Energy at Play Design Challenge *(25-45 minutes)*

1. Introduce the Challenge: Design and build a device that transforms potential energy (elastic or gravitational) to kinetic energy, and transfers the kinetic energy to a ball in order to move 1 meter and hit a target.
2. Introduce the Constraints:
    - Your device must show and you must explain:
        - the kind of potential energy your device stores
        - how that potential energy is transformed to kinetic energy
        - where the kinetic energy goes after being transferred to the ball
    - You can use your original design or create something completely new.
    - The ball must travel about 1 linear meter in any direction towards the designated target.
    - You can only use the materials provided.
    - You can visit the research station at any time to get ideas for your design.

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- Each group member must participate in the design, construction, and operation of the device.
- You will be allowed to test your device as you work.

3. Build: Give students about 20-30 minutes to build. Instructor should ask open-ended questions to help guide students through the design process, but should also allow students space to tinker. Testing during this build period should be encouraged.
4. Demonstration: Have students demonstrate their device for the class. If students have not completed their device, or their device did not function as expected, ask them *how the device would have worked.*
5. Reflection: Each group of students will explain their design strategy and how their device uses energy, force, and motion. The instructor should ask leading questions and point out other facets of the student's designs (such as simple machines).
   - Teaching Points:
     - Energy comes in many forms and can be changed from one form to another.
     - Kinetic energy is the energy of motion and potential energy is the stored energy of position.
     - A force is a push or a pull. An object can have two or more forces that act on a single object including: gravity, elastic forces due to tension or compression, and friction.
     - There is more to designing a device than building it. You must consider the resources available and the limitations of a design.
     - Brainstorming, teamwork, and testing are important parts of the design process.
     - Complex problems and machines can be simplified by looking at smaller aspects of them.
   - Questions:
     - Did you continue to work on your original design or try something new?
     - How does your toy transform potential energy (elastic or gravitational) into kinetic energy?
     - How does your toy transfer energy to the ball to make it move?
     - Did you do any research to inform your design? How did it help you?
     - If you had more time what would you add, change, or do differently?

Extensions

1. Have students create their own toys or improve upon an old favorite. Bring these toys to class to begin the conversation about potential and kinetic energy.
2. Create a larger ball machine using whatever supplies are available to the students and market it (create packaging, advertisements, commercials, etc.)
3. Hold a Rube Goldberg Machine contest for the class.
4. Have the class create a giant Rube Goldberg Machine with each team of students creating one portion, receiving and passing the energy from team to team.