Bobsled Blitz

Design Challenge Learning

The Tech
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201 S. Market St.
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Students explore the effects of gravity, friction and air resistance upon acceleration when they design their own bobsleds. The objective is to design a bobsled that reduces run times with each attempt. As students iterate through this design challenge, they gain firsthand experience in the design process.

Grades 3-12
Estimated time: 3 sessions (30-45 minutes each)

Student Outcomes:

1. Students will be able to demonstrate their knowledge of Potential and Kinetic Energy by designing a device that slides down an inclined plane to pass a finish line.
2. Students will be able to iterate on a design that decreases run times by reducing friction and drag.
3. Students will be able to explain design considerations based on concepts of aerodynamics, acceleration, velocity, and terminal velocity.
4. Students will be able to utilize the three step design process to meet an engineering challenge.

Next Generation Science Standards
Grade 3-5: *Engineering Design* 3-5-ETS1-1, 3-5-ETS1-2, 3-5-ETS1-3
Grade 3: *Physical Science* 3-PS2-1
Grade 4: *Physical Science* 4-PS3-1, 4-PS3-4
Grade 5: *Physical Science* 5-PS2-1
Grade 6-8: *Engineering Design* MS-ETS1-1, MS-ETS1-2, MS-ETS1-3, MS-ETS1-4; *Physical Science* MS-PS2-2, MS-PS3-1, MS-PS3-2, MS-PS3-5
Grade 9-12: *Engineering Design* HS-ETS1.1, HS-ETS1.2, HS-ETS1.3; *Physical Science* HS-PS2-1, HS-PS2-6, HS-PS3-2, HS-PS3-3,

Common Core Language Arts-Speaking and Listening
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
Grade 7: SL.7.1b-d
Grade 8: SL.8.1b-d
Grade 9-10: SL.9-10.1b-d
Grade 11-12: SL.11-12.1.b-d

California Science Content
Grade 3: *Physical Science* 1.b; *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
Grade 7: *Investigation and Experimentation* 7.a, 7.c-e
Grade 8: *Physical Science* 1.a-e, 2.a-g; *Investigation and Experimentation* 9.a-b
Grade 9-12: *Physics* 1.a-f, 2.a-g; *Investigation and Experimentation* 1.a-d

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Vocabulary:

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

- Acceleration: The rate at which an object changes its velocity.
- Air Resistance: The friction that acts on something moving through air.
- Energy: The ability to do work. Appears in many forms, all of which are either kinetic or potential.
- Force: A push or a pull. An influence on a body or system, causing or tending to cause a change in movement or shape.
- Friction: Forces resisting motion between one set of molecules and another due to electrical attraction and repulsion, usually between two solid surfaces; static before motion starts and kinetic during motion.
- Gravitational Potential Energy: 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.*
- Inertia: The tendency of matter to remain at rest if at rest, or if moving, to keep moving in the same direction, unless affected by an outside (or unbalanced) force.
- Kinetic Energy (KE): Energy of motion. Includes heat, sound, and light (motion of molecules).
- Mass: The amount of matter that is contained by an object.
- 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).
- Momentum: The quantity of motion of a moving object, equal to the product of its mass and its velocity.
- Newton's Law of Conservation of Energy: 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.
- Newton's Laws of Motion:
    - 1st Law (Law of Inertia): An object at rest tends to stay at rest and an object in motion tends to stay in motion with the same speed and in the same direction unless acted upon by an unbalanced force.
    - 2nd Law: When an unbalanced force acts on a body, it is accelerated in the direction of the force; the magnitude of the acceleration is directly proportional to the force and inversely proportional to the mass of the body… F=ma.
    - 3rd Law: Forces always occur in pairs. If object A exerts a force, *F*, on object B exerts an equal and opposite force, *-F*, on object A. Or "Every action has an equal and opposite reaction."
- Potential Energy (PE): Energy of position; energy that is stored and held in readiness. Includes chemical energy, such as fossil fuels, electrical batteries, and food we eat.
- Terminal Velocity: The velocity attained by an object wherein the resistive forces counterbalance the driving forces, so motion is without acceleration.
- Speed: How fast an object is moving. The distance traveled over time.
- Velocity: The speed of something in a given direction.

Resources:

- How Bobsledding Works: An article by "How Stuff Works" on bobsledding. It provides information on the rules of the sport, technical information about courses and sleds, as well as physics on how everything works. http://adventure.howstuffworks.com/outdoor-activities/snow-sports/bobsled.htm

- Aerodynamics: An article posted to "Live Science" that explains the basics of aerodynamics as it applies to a variety of vehicles. http://www.livescience.com/47930-what-is-aerodynamics.html

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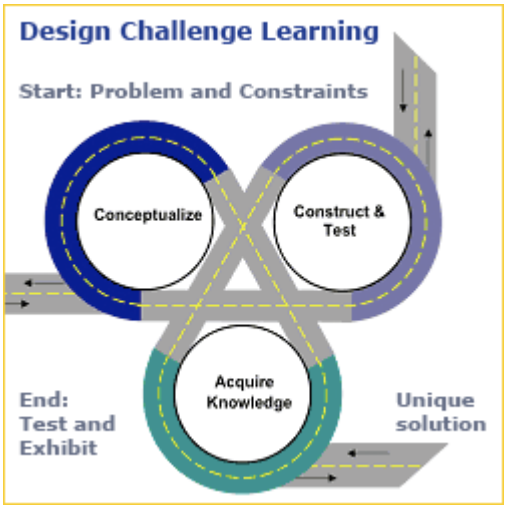
- Engineering Faster and Safer Bobsleds: A video explaining the engineering challenges associated with making sleds faster and tracks safer. The video is narrated by Michael Scully, of BMW DesignWorks USA, and mechanical engineer Mont Hubbard, professor emeritus at the University of California, Davis. http://science360.gov/obj/video/53c11379-241c-460b-b82c-4ed7e4f76631/science-winter-olympic-games-engineering-faster-safer-bobsleds

- PhET Interactive Simulations: Administered by the University of Colorado Boulder, the website provides a variety of interactive simulations for science and math. One simulation allows students to manipulate a ramp in order to discover force, energy, and work. https://phet.colorado.edu

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.

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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:

- Plastic Drinking Straws
- Craft Sticks
- Wooden Skewers
- Toothpicks
- Paper Clips
- Twist Ties
- Rubber Bands
- Pipe Cleaners
- Masking Tape
- Scissors
- Cardstock
- Cardboard

Testing Supplies:

- Stopwatch
- Scale
- Rain Gutters (race track)
- Wood Blocks (braces for the rain gutters)

Lesson Plan:

Session 1: Bobsled Challenge and Reflection *(30-45 minutes)*

1. Introduce the Challenge: Design and build a bobsled using the provided materials to race down the rain gutter track.
2. Introduce the Constraints:
   - Each bobsled must weigh 8 grams or less.
   - Bobsleds must be able to fit behind the black line on the racetrack.
   - You must use only the materials provided.
   - Everyone on the team must be included (2-4 engineers).
3. Build: Give students about 20 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.
4. Demonstration: Have students demonstrate their bobsled designs. 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 bobsled uses energy, forces, and motion to complete the track. The instructor should ask leading questions to get at the science behind the designs.
   - Questions:
     - When the bobsled reaches the bottom of the track and stops, what kind of energy does it have? Potential? Kinetic?
     - What kind of energy does the bobsled have if it is only halfway down the track?
     - How would a heavier bobsled affect the run?
     - How would surface area affect your bobsled?
     - How does shape affect your bobsled?
     - Questions about specific design choices: Why did you use a…? What does the… do? How did you solve…?

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Session 2: Directed Instruction *(30-45 minutes)*

1. Questions for teaching points:
    - How would you describe the energy associated with your bobsled?
    - What would happen if you make your bobsled heavier?
    - What would happen if more of your bobsled were in contact with the track?
    - Is it possible to achieve a faster run-time just by changing the shape of your bobsled?
2. Friction: When things rub against each other, they generate friction. Materials that slide down the track more easily have less friction, less energy is lost, and so the track time is faster.
    - Demonstration Ideas:
        - Have students rub their hands together. Do they feel the heat? That is the energy from the movement of their hands being converted to thermal energy (i.e. heat) through friction. Potential energy that becomes heat cannot become motion. Low friction means less energy is lost to heat, leaving more energy for motion; therefore, the bobsled goes faster.
        - Get a paperclip and a rubber band. Ask which one they think will go faster down the track. Drop the paperclip in one track and the rubber band in the other. The paperclip will slide down the track while the rubber band will stick at the top. Which one has higher friction? *The rubber band.* Things with more friction are "stickier." Kids seem to have an innate understanding that sticky things don't move well.
    - Questions:
        - How does material choice affect the bobsled's race time?
        - How does surface are affect the bobsled's race time?

3. Aerodynamics: Air resistance, or air friction. When something moves through air, the air molecules rub against the object and create air friction. Friction slows an object down. Air friction is one form of drag. The larger the area hitting the air, the greater the number of air molecules hitting the object at any moment in time, and more friction is created. More friction means the object slows down more. This is why a parachute works.
    - Demonstration: Get two pieces of paper. Reduce the surface area of one piece by crumpling it up. Drop the two pieces of paper. The crumpled paper will hit the ground first. Gravity accelerates the two objects toward the earth at the same rate. The crumpled paper goes faster because there is a smaller surface for the air to hit, which means less air friction, which means it loses less speed.
    - Additionally: The other factor that affects air resistance is the object's velocity. If an object can pass through more air space in a given amount of time, it will collide with more air molecules than the same object with a slower velocity. The more air molecules it hits, the more air friction is created and the more speed is lost.
    - Questions:
        - How does shape affect a bobsled's run time? What shapes are more effective?
        - What other vehicles make design considerations based on aerodynamics? What shapes do these vehicles utilize?
4. Terminal Velocity: Acceleration due to gravity = Deceleration due to air resistance. As an object falls it will continue to speed up. As it speeds up the force due to air resistance will increase. That force is accelerating the object in the opposite direction of its movement, or causing it to decelerate. When the force of air resistance matches the force of gravity, the object is being accelerated and decelerated at the same rate. That means there is no acceleration at all. It doesn't mean the object stops falling. It just stops falling faster.
    - Demonstrations:
        - Get a stack of cards (index or playing). Rubber band the stack together except for one card. Point out the bottom of the stack of cards and the single card have the same surface area that will hit the air when they are dropped. Hold the stack of cards and the single card at the same

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height and drop them. The stack of cards will hit the ground first. This is because the stack of cards has more mass so it takes longer to reach the speed that will create enough air resistance to counteract the acceleration due to gravity. If you dropped the single card and the stack in a vacuum they would fall at the same rate.

- Get an empty matchbox and a matchbox full of pennies. Slide them both down the track. The matchboxes have the same profile to affect their aerodynamics. Because the box with the pennies is heavier, it will slide down the track faster.

- Questions:
  - How does terminal velocity affect the bobsleds?

    NOTE: We want our bobsled to accelerate as long as possible so it reaches a high speed. Gravity will speed the bobsled up. Air resistance and friction will slow it down. Eventually, gravity will balance air resistance and friction and stop acceleration. This will be your terminal velocity. The bobsled cannot go faster than this. We want to delay reaching terminal velocity as much as possible so the bobsled accelerates as long as possible. A heavier bobsled will create a larger gravitational force (to create the same acceleration). It will take more air resistance to counteract the larger force of gravity in a heavy object. The more air resistance you need, the faster the object must be going to create it, the longer the bobsled must accelerate to reach that speed. <u>This is why we want to add weight to our bobsleds.</u>

Session 3: Bobsled Redesign and Reflection *(30-45 minutes)*

1. <u>Introduce the Challenge</u>: Redesign and build a bobsled using the provided materials to race down the rain gutter track in order to decrease the initial run time.
2. <u>Introduce the Constraints</u>:
   - Each bobsled must weigh 8 grams or less.
   - Bobsleds must be able to fit behind the black line on the racetrack.
   - You must use only the materials provided.
   - Everyone on the team must be included (2-4 engineers).
3. <u>Build:</u> Give students about 20 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.
4. <u>Demonstration</u>: Have students demonstrate their bobsled designs. If students have not completed their device, or their device did not function as expected, ask them *how the device would have worked.*
5. <u>Reflection</u>: Have each group of students explain their design strategy and how their bobsled uses energy, force, and motion to complete the track. The instructor should ask leading questions to get at the science behind the designs.
   - <u>Questions</u>:
     - How did you change your original design? What affect did this/these change(s) have upon the performance of your bobsled?
     - Did you do anything specific to increase the aerodynamics of your bobsled?
     - Did you do anything specific to help your bobsled accelerate longer (i.e. decrease friction, delay terminal velocity by adding weight and increasing aerodynamics)?
     - If you had more time what would you add, change, or do differently?
     - If you had another opportunity to redesign, do you feel you could make your bobsled run even faster?