Balloon Astronaut

Design Challenge Learning

The Tech Museum of Innovation

201 S. Market St.
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Students investigate properties of materials and colliding objects by designing spacesuits for balloon astronauts. The objective is to design spacesuits that can withstand the hazards of high velocity impacts from space debris and meteoroids. As students iterate through this design challenge, they gain firsthand experience in the design process.

Balloon Astronaut[1]

Grades 2-8

Estimated time: 45 minutes

Student Outcomes:

1. Students will be able to design and build a protective device to keep their balloon astronaut from popping when impaled by a falling nail.
2. Students will be able to explain design considerations based on material characteristics, and concepts of energy, velocity, and the physics of colliding objects.
3. Students will be able to utilize the three step design process to meet an engineering challenge.

Next Generation Science Standards

Grade 2-5: *Engineering Design* K-2-ETS1-1, K-2-ETS1-2, K-2-ETS1-3, 3-5-ETS1-1, 3-5-ETS1-2, 3-5-ETS1-3
Grade 2: *Physical Science* 2-PS1-1, 2-PS1-2
Grade 3: *Physical Science* 3-PS2-1
Grade 4: *Physical Science* 4-PS3-1, 4-PS3-3, 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-PS2-1, MS-PS2-2, MS-PS3-2, MS-PS3-5

Common Core Language Arts-Speaking and Listening

Grade 2: SL.2.1a-c, SL.2.3, SL.2.4a
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

California Science Content

Grade 2: *Physical Science* 1.a-c; *Investigation and Experimentation* 4.a, 4.c-d
Grade 3: *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.b-c

[1] Developed from a program designed by NASA.

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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.
- 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.
- 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.
- Momentum: The quantity of motion of a moving object, equal to the product of its mass and its velocity.
- Newton's Law of Momentum Conservation: The amount of momentum remains constant – momentum is neither created nor destroyed, but only changed through the action of forces.
- 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.
- Speed: How fast an object is moving. The distance traveled over time.
- Terminal Velocity: The velocity attained by an object wherein the resistive forces counterbalance the driving forces, so motion is without acceleration.
- Velocity: The speed of something in a given direction.

Resources:

- 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
- Liquid Body Armor: A facilitation guide provided by NISE Network on how nanotechnology is being used to create new types of protective fabrics. It includes an experiment/demonstration utilizing "Oobleck" to demonstrate the techniques scientists utilize when creating protective, lightweight, and flexible fabrics. www.nisenet.org/catalog/programs/liquid_body_armor
- NASA Spacesuits: Two websites provide an interactive guide to NASA spacesuits. They discusses the mission objectives and the design considerations for each suit. www.nasa.gov/externalflash/nasa_spacesuit/ and www.nasa.gov/audience/foreducators/spacesuits/home/clickable_suit.html#.VVuXUvIViko

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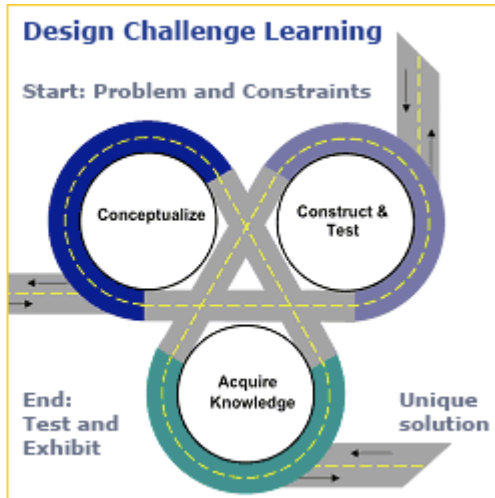
- Using Science to Provide Impact Protection for Mobile Devices: An article on Geek Dad that covers information about the development of impact-protective materials by Tech 12. http://geekdad.com/2013/12/tech21-using-science-provide-impact-protection-mobile-devices/

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 the 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.

Team Materials (2-3 Engineers):
- Rubber bands
- String
- Elastic
- Plastic grocery bags/ trash bags
- Tissue paper
- Aluminum foil
- Netting
- Cellophane
- Paper towels
- Newspaper/phone book pages
- Wax paper
- Scissors
- Paper grocery bags

Testing Supplies:
- 7ft or longer piece of PVC pipe
- Large Nail that is able to fall down the PVC pipe
- Inflated balloons/water balloons

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Lesson Plan:

Introduction *(5 minutes)*

1. One of the many jobs of astronauts is that of mechanic, performing maintenance and fixing the man-made objects in space. In order to do this work, astronauts must exit the durable spacecraft and perform the dangerous work of extravehicular activity (EVA)– activities that take place outside their spacecraft.
2. What hazards are faced by astronauts performing extravehicular activities (EVAs)? What systems need to be in place in order to protect astronauts? (*Note: Popular Mechanics published an article on the top 10 dangers of past EVAs http://www.popularmechanics.com/space/g1307/10-of-the-most-dangerous-space-walks-ever-done/?slide=10*)
3. There are more than 500,000 pieces of debris, or "space junk" in orbit of Earth, traveling at speeds of up to 17,500 mph. At these speeds, even small pieces of debris can cause damage to satellites, spacecraft, and their human occupants. (*Reference on Space Debris: http://www.nasa.gov/mission_pages/station/news/orbital_debris.html*)

The Challenge *(20 minutes)*

1. Introduce the Challenge: Design an outfit for your balloon astronaut that will protect it from the effects of being hit by small space debris moving at high speeds.
2. Introduce the Constraints:
   - Protective wear must fit snugly on the astronaut.
   - No adhesives may be used.
   - Maximum of four layers may be used.
   - Must be flexible.
   - Must consist of at least three different materials.
3. Build: Give students about 15 minutes to build and test. The instructor should ask open-ended questions to help guide students through the design process, but should also allow students space to tinker.
4. Testing: During the build time student should be able to test and iterate their designs freely. Place the balloon astronaut in the testing space. Place the PVC pipe directly over the balloon astronaut and drop the nail pointed-side fist down the pipe. There should be supervision at the test area to ensure students are safely testing their gear – no body parts should be in the test area while the nail is falling. A successful design is represented by an intact balloon.

Demonstration and Reflection *(20 minutes)*

1. Demonstration: Have students demonstrate their devices one team at a time. If students have not completed their device, or their device did not function as expected, ask them *how the device would have worked.*
2. Reflection: Have each group of students explain their design strategy and how their device protected the astronaut. The instructor should ask leading questions to get at the science behind the designs.
   - Teaching Points:
     - There is more to designing a device than building it. You must consider the resources available and the limitations of a design.
     - Brainstorming, testing, and teamwork are important to a successful design process.
     - The many properties of materials make different materials suitable for different purposes.

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  - A collision is an event in which two or more bodies exert forces on each other.
  - Structures can help spread the force of an impact over a broad area.
  - Some materials are better able to absorb impact energy than others.
- Questions:
  - Which layer(s) was penetrated? Why?
  - How can you change your design or use of materials?
  - Would you add other layers or materials if you were to redesign your spacesuit?
  - What do you think would have happened if the nail was more massive?
  - What do you think would happen if the nail was dropped from a greater height?
  - Do you think that astronauts can be protected for all types and sizes of space debris?
  - Do you think it's important for an astronaut's space suit to fit snuggly? Why?

Extensions

1. Explore how nanotechnology is being used to develop lightweight materials that absorb impacts. Experiment with the properties of Oobleck. Can it protect an astronaut?
2. Instead of having something impact the astronaut, launch the astronaut using a slingshot against a wall or into a freefall. Use water balloons for this type of activity.
3. Utilize different lengths of PVC pipe in order to test different dropping-heights. Use these tests as an opportunity to discuss how changes in distance affects the object's energy.
4. Utilize different sizes of nails/projectiles. Use these tests as an opportunity to discuss how changes in mass/weight affects the object's energy.