INSIDE SCIENCE TV: Bottles, Bubbles And Breakages

STEM Lesson Plan / Adaptable for Grades 9–12

Lesson plan developed by T. Jensen for Inside Science and the American Institute of Physics

About the Video **(click here to see video)**

Party tricks in the science classroom? The video shows how a rubber hammer striking the mouth of a glass bottle filled with water can cause the bottom of the bottle to shatter or fail. Jesse Daily, Mechanical Engineer at Brigham Young University, explains how it was previously (and erroneously) thought that the bottom of the glass was shattered by a pressure wave. Daily and Truscott (PhD, Mechanical Engineer) use high-speed video photography and an accelerometer to determine what causes the failure of the bottom portion of water-filled glass bottles.

Related Concepts

acceleration	cavitation	inertia
acoustics	fluid dynamics	pressure

Bell Ringers

Use video to explore students' prior knowledge, preconceptions, and misconceptions. Have students write or use the prompts as discussion starters.

Time	Video content	Students might…
0:00–0:05	Series opening	
0:06–0:11	Party trick breaks water filled bottle	[*with the audio off*] Have students make written predictions about what causes the bottom portion of a water-filled glass bottle to shatter when the mouth of the bottle is struck with a rubber hammer. Predictions should be supported with physics concepts. (You can play the video at full screen without the label *Bottles, Bubbles And Breakages* showing by keeping your cursor out of the screen.) After the narrator poses the question *But what causes it to break?* have students share their thoughts. Use your computer's cursor to highlight the word *Bubbles* at the top of the page. Students might discuss/write about what bubbles might have to do with the shattering of solid glass bottles.
0:12–0:19	The 'question' engineers want to answer	

0:20–0:22	Introduction to Jesse Daily, M.E. who explains previous assumptions	
0:23–0:35	Mechanical engineers Daily and Truscott decide to ‘get to the bottom’.	
0:36–0:42	High speed video camera reveals ‘secret’ to breaking bottle	[*with the audio off*] Students might speculate (citing supporting knowledge) on what they observe. [*with the audio off*] Teams of students could design an investigation that might allow them to more fully explain what is happening to the bottle.
0:43–0:54	Importance of collapsing bubbles	
0:55–1:14	Acceleration to bottle causes cavitation	
1:15–1:20	Truscott explains timing of bubble formation and collapse	
1:21–1:30	Data from an accelerometer proves what causes bottle to break	The narrator proclaims, “confirm that the bottle breaks after the bubbles collapse….” Students might copy and annotate the graph to show how it supports the narrator’s claim.
1:31–1:57	Closing credits	

Explore and Challenge

After prompting to uncover prior knowledge, use video for a common background experience and follow with a minds-on collaboration.

1. Explore readiness to learn from the video with prompts such as the following:
- One experience I have had with acceleration and inertia is….
- Water can be made to boil by….
- Things that cause glass to fail include….
- Aerodynamics and hydrodynamics are related in that….
- The force required to break a glass bottle can be determined by….
- Constraints that might limit the formation of bubbles when the bottle is struck include….
- Water is/is not the only fluid that could cause this failure because….

2. Show the video and allow students to discuss what they observed.

3. Challenge students, in groups, to design a procedure to determine how much force is required to generate the bubbles that allow the glass bottle to be shattered. Each group should be able to explain and justify their designs using concepts and math previously covered in class.

Investigate, Compare, and Revise

Use video as a springboard for students to apply engineering design processes and science concepts to answer questions and solve problems.

Pose Questions

Challenge students to pose questions based on the video that can lead to questions they can answer using scientific methods. For example: ***What information would we need to be able to predict the force needed to break a bottle based on the mass of the bottle?*** Encourage a wide range of questions and allow students to choose. (While a rubber mallet applies the force in this video, others available on the Internet show that a bottle might be broken by the hit of a person's hand).

Possible Equipment and Materials

- bottles with different masses and shapes
- an identified method to control the amount of water placed in each bottle
- a method to deliver a hit with a consistently increasing force
- an identified procedure to safely hold the bottle as the hit is applied
- a method, similar to that depicted in the video, to safely collect broken glass.
- video camera or cell phone camera with slow motion filming capabilities
- calculator/spread sheet to analyze data
- materials to create graphs that can be shared with the class
- safety goggles, rubber aprons, safety gloves, and other necessary safety equipment

Allow students a brief period of time to examine and manipulate available materials. Doing so often aids students in refining the direction of their investigation or prompts new ones that should be recorded for future exploration. Since conversation is critical in the science classroom, allow students time to discuss which materials they will use and why.

Safety Considerations: Review safe use of tools and measurement devices as needed. Augment your own safety procedures with NSTA's Safety Portal at www.nsta.org/safety/. Make certain students understand that they must NOT attempt experiments at home "just for fun or to see what will happen." Do not make assignments that require students to carry out any experiments at home. Only supervised activities in the school setting and directed by the teacher should be done.

Set the Stage

Use prompts to get students thinking about how they will answer their question:

- One way we can control the force with which the mouth of a bottle is struck is….
- The force with which a water-filled bottle is broken and the mass of the bottle are/are not related because….
- The bottle doesn’t have to be full of water because….
- Things that must be controlled to conduct this investigation reliably include….
- The item that supplies the hit to the mouth of the bottle must deliver the hit….
- It will necessary for the mouth of the bottle to be struck at a consistent angle because….
- Safety issues raised by this investigation include….

Investigate

Determine the appropriate level of guidance you need to offer based on your student’s knowledge, creativity, ability levels, and available materials. Review safe use of tools and measurement devices as needed. Augment your own safety procedures with NSTA’s Safety Portal at www.nsta.org/safety/.

Students might create a system that allows them to determine the force required to break the bottle based on the bottle’s mass. Factors students would consider in their investigation is the way the bottle is held (by the neck, suspended, etc.), how to control the amount of force (have the mass dropped along a slider, propelled by hand, swung on a hinged lever, etc.), the speed of the strike, and what would be the most effective material with which to strike the blow.

A major constraint in any design investigation is time. Give students a clear understanding of how much time they will have to design their investigation to determine the relationship between the force with which a water-filled glass bottle must be hit to break and the mass of the bottle itself.

Compare/Revise

After demonstrating and communicating information backed by evidence to the class about their methodology and reflecting on the practices and methods of other groups, allow teams to go through a redesign process to improve their methodology. Encourage students to identify limitations of their materials and testing process. Students should also consider if there were variables not identified earlier that had an impact on their methods. Students should quickly make needed revisions to their methods and retest.

Build Science Literacy through Reading and Writing

Use the video as engagement to spark interest in science, engineering design, and careers. Related resources help build science literacy.

Related Resources

- http://www.chefsteps.com/activities/the-physics-of-blending-cavitation
- http://www.npl.co.uk/acoustics/ultrasonics/research/high-power-ultrasound-and-acoustic-cavitation-introduction
- http://www.theguardian.com/science/video/2012/aug/17/cavitation-beginners-building-fastest-ship-world-video
- http://web.mit.edu/hml/ncfmf/16CAV.pdf
- http://www.brighthubengineering.com/fluid-mechanics-hydraulics/7228-cavitation-why-did-my-pipe-burst/

Reading Strategy: T Chart/Two-Column Notes Do your students think it's not easy to breeze through science and technical reading passages? They are right. Just the density of text on the page can be too much for some students. One strategy that can help is to encourage students to break the reading passage up into chunks that are more manageable. Text can be broken up by paragraph or into sections by topics. Students might use horizontal lines between sections. They could also draw rectangles around sections. Some students might benefit from using a T Chart (topic on one side, what was learned about it on the other) or taking Two-Column Notes. A two-column notes format requires students to participate with what they are reading. The first column identifies the main idea of each chunk and the second column contains key supporting details.

Writing Strategy: T Chart/Two-Column Notes After students have read/watched the material closely you might give them a writing assignment that allows them to integrate and evaluate the texts and video in order to examine the science behind the manner in which bubbles can break a fairly strong glass bottle. The text/video provides a wide look at cavitation across several areas. Students could use their T Charts or Two-Column Notes to quickly generate an outline from which to write about the concept. For example: ***You are a reporter for the Universe, Brigham Young's campus newspaper. Use your outline to generate a news release for the Universe, whose readers vary greatly in their understanding of science concepts. Be sure to include evidence from the video and readings to support your claims.***

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NATIONAL STANDARDS CONNECTIONS

Next Generation Science Standards

Visit the URLs to review the supportive Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts for these connected Performance Expectations.

MS-PS4 Waves and their Applications in Technologies for Information Transfer
http://www.nextgenscience.org/msps4-waves-applications-technologies-information-transfer
MS-PS4-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

MS-PS2 Motion and Stability: Forces and Interactions
http://www.nextgenscience.org/msps2-motion-stability-forces-interactions
MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

MS-PS1 Matter and its Interactions
http://www.nextgenscience.org/msps1-matter-interactions
MS-PS1-4. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

MS-ETS1 Engineering Design
http://www.nextgenscience.org/msets1-engineering-design
MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

HS-PS3 Energy
http://www.nextgenscience.org/hsps3-energy
HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).
HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*
HS-PS3-4. Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).
HS-PS3-5. Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

HS-PS2 Motion and Stability: Forces and Interactions
http://www.nextgenscience.org/hsps2-motion-stability-forces-interactions
HS-PS2-1. Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.
HS-PS2-3. Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.*

HS-ETS1 Engineering Design
http://www.nextgenscience.org/hsets1-engineering-design
HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

HS-ETS1-4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

Common Core State Standards for ELA & Literacy in Science and Technical Subjects

Visit the URLs to find out more about how to support science literacy during science instruction.

College and Career Readiness Anchor Standards for Reading

http://www.corestandards.org/ELA-Literacy/CCRA/R/

1. Read closely to determine what the text says explicitly and to make logical inferences from it; cite specific textual evidence when writing or speaking to support conclusions drawn from the text.
6. Assess how point of view or purpose shapes the content and style of a text.
7. Integrate and evaluate content presented in diverse formats and media, including visually and quantitatively, as well as in words.
8. Delineate and evaluate the argument and specific claims in a text, including the validity of the reasoning as well as the relevance and sufficiency of the evidence.

College and Career Readiness Anchor Standards for Writing

http://www.corestandards.org/ELA-Literacy/CCRA/W/

Visit the URL to review the supportive Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts for these connected Performance Expectations.

1. Write arguments to support claims in an analysis of substantive topics or texts using valid reasoning and relevant and sufficient evidence.
2. Write informative/explanatory texts to examine and convey complex ideas and information clearly and accurately through the effective selection, organization, and analysis of content.
7. Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.
8. Gather relevant information from multiple print and digital sources, assess the credibility and accuracy of each source, and integrate the information while avoiding plagiarism.
9. Draw evidence from literary or informational texts to support analysis, reflection, and research.

Feedback

Inside Science welcomes your feedback on this STEM lesson plan. Please send your comments to Laleña Lancaster of Inside Science at ldlancas@aip.org.