Bottle Rockets (Junior/Senior)

Instructional style requires hands-on learning and teaching with an emphasis on creativity and collaboration between students. This style of teaching involves emphasizing the showing, telling and exploration of projects and physical demonstrations, while still ensuring that students understand the underlying concepts. During discussions, spontaneous events and comments are cherished and used to further explore concepts. The instructor will lead by example and transform the way teaching is done, moving away from the "teacher is the source of all knowledge" style of teaching toward harnessing and using everyone's skills and differences.

Summary

The Bottle Rockets is a hands-on activity where students build and test a rocket out of a 2L soda bottle. Students will get multiple chances to design and iterate on their bottle rocket trying to accomplish various exciting challenges.[1] By the end of the activity the students involved should understand the importance of the iterative process of design and the cool and fun outcomes you get when you keep improving on a design.

[1] The timing for these challenges is variable. You may choose to only complete certain challenges according to student interest. If time allows move on to further challenges.

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Safety

This activity involves pressurized bottles launching at up to maximum, 60 psi so to ensure everyone is safe make sure everyone is wearing goggles during discussions, building, demos, and testing. During rocket launching make sure there is always an adult present watching the launch and make sure everyone stays back at least 25 ft.

Learning goals

- Iterative process of design
- Center of mass
- Pressure
- Air resistance
- Functional requirements
- Team work
- Fail fast
- Velocity
- Acceleration
- Newton's 3rd Law
- High Speed Photography
- Working with PVC

*Note: These learning goals should be covered naturally through each activity. It is okay if they aren't covered throughout the activity because at the conclusion of the bottle rocket activity each learning goal is clearly explained and reiterated.

Introduction

10-30 min

Location: outside or inside (this entire bottle rocket module can be done outside)

To introduce the activity, gather everyone in a big circle and start by asking questions that get students thinking and talking to each other such as…

> "Has any of you ever looked up at the sky and seen something interesting?" (stars, sun, moon, airplanes)
>
> "Humans have created a way of getting to the moon and other planets, anyone know what it is?" (rockets)
>
> "Why do you think we want to explore space?" (life, other planets,…)
>
> What do you think makes rockets move in the air?" (Newton's Third Law)

Tell the students that today they will get to design build rockets of their own in pairs.

It's recommended that you explain to the students that there will be a series of challenges they will get to tackle. Also explain that we will all learn from each other's designs and periodically stop working to have a discussion if we see an interesting design or a design flaw.

It is now recommended that you then segue into Challenge #0 which is a demo of diet coke and mentos.

Challenge #0: Diet Coke and Mentos

15-30 min

Location: outside or inside

Materials

2L diet coke (unopened) …… 1 for the whole class

Small pack of mentos …… 1 for the whole class

(optional) Small bottle regular coke (unopened) …… 1 for the whole class

Preparation tips

This challenge is ideally done outside in an open area because it gets messy. Designate an open area where you would not mind diet coke spilling all over the place.

Challenge Description

The class tackles the challenge as a group. Go outside, gather the class in a circle.

Show the diet coke and mentos. Say you're holding a bottle of coke and a pack of mints. Now surprise the kids.

Demonstrate by having one of the students open the mentos, and drop a mentos inside the diet coke.

"What just happened?" (mentos reacted with diet coke)

"Why did it happen?" (pressure build-up inside coke bottle)

"What is pressure and what are some examples of pressure?"

"What do you think would happen if we dropped in the mentos and closed the cap of the coke bottle?"

"What would happen if we dropped in the mentos and flipped the bottle neck down? (bottle would shoot up)

"Would the same thing happen with mentos and regular coke?" (yes but the geyser won't go up as high)

Demonstrate with regular coke if you wish.

"How do you think this experiment relates to rockets?" (chemical reaction, Newton's Third Law)

"What are some examples of chemical reactions?" (fire, cooking)

Is the mentos and diet coke a chemical reaction? (it's debatable)[1]

Troubleshooting

*Newton's Third Law – For every action there is a reaction. (ex. If I push you, you're pushing me back even though it doesn't seem like it)

[1] http://www.eepybird.com/featured-video/coke-and-mentos-featured-video/science-of-coke-mentos/

Challenge #1: Build a Simple Bottle Rocket

15 – 60 min

Location: outside (or inside, with testing done outside)

Materials

Empty 2L Liter soda bottle …….. 1 for the whole class

Rocket launcher …….. 1 for the whole class

Bicycle pump w/ pressure gauge …… 1 for the whole class

1 liter of water …….. 1 for the whole class

Vaseline …… 1 for the whole class

Preparation tips

Designate an open area outside where you can launch a bottle rocket. The area should NOT have tall buildings or trees around it, should NOT be covered and should be at least 50 x 50 ft. An ideal space is a soccer or football field.

Challenge Description

The class tackles the challenge as a group. Go outside, gather the class in a circle and offer an empty 2L soda bottle as a rocket…

"What do we need to shoot this bottle off?" (pressure)

Demonstrate by first putting a dab of Vaseline on the O-ring and placing bottle on the rocket launcher but DO NOT secure it down into the zip ties of the rocket launcher. Pressurize until take off.

Ask…

"What can we add to this setup to make the rocket go up higher?"
(pressure, water,…)

Try out some of the students suggestions and launch again. (Note: Just play around with the pressure and add water DO NOT add fins or a nose cone yet)

Ask again…

"What can we add to the rocket to make it go up higher?" (fins, mass, nose cone)

Based on student answers, **introduce** new Challenges such as increasing rocket's height and stability and allow students to go off and build back in the classroom. During building the students can build, test, ask questions in an open manner meaning it does not have to be structured.

Note: During testing, do not exceed 60 psi.

Troubleshooting

*Why Vaseline?

Lubricating the o-ring with Vaseline prolongs the life of the o-ring and also reduces friction between the bottle and the o-ring.

Challenge #2: Increase the Rocket's Stability

30 – 60 min

Location: outside (or inside, with testing done outside)

Materials

Empty 2 Liter soda bottles …… 1 per student

Rocket launcher …….. 1 for the whole class

Bicycle pump w/ pressure gauge …… 1 for the whole class

Corrugated plastic …… 12" x 3" sheet per student

Duct tape …… 1-2 rolls

Mason string …….. 10 ft

Vaseline …… 1 for the whole class

Preparation tips

Designate an open area outside where you can launch a bottle rocket. The area should NOT have tall buildings or trees around it, should NOT be covered and should be at least 50 x 50 ft. An ideal space is a soccer or football field.

Lay out the materials and tools in the classroom.

Challenge Description

Show a picture of a real rocket. Ask the students to list properties of a rocket. (nose cone, fins, etc.)

Go outside.

Test the rocket for its ability to fly straight by taping a string to its center of mass and twirling it in a circle around their head. (Show students how to find the center of mass of the rocket by attempting to balance the rocket on their finger.)

Ask...

"How can we make the rocket fly straighter?" (fins)

Challenge students to go off and improve on their rocket so that it flies straighter by adding fins (you can use corrugated plastic for fins).

Suggest adding fins in different orientations and show alternate fin designs to allow rocket to spin and maximize height.

(Note: When you see an interesting example of fins stop the class and share)

Below is a picture of a bottle rocket with fins and a nose cone.

Note: During testing, do not exceed 60 psi.

Troubleshooting

*How do I find a rocket's center of mass?

Put it on your finger and see where it balances.

Challenge #3: Increase the Rocket's Height

30 – 60 min

Location: outside (or inside, with testing done outside)

Materials

Existing bottle rocket …… 1 per student

Rocket launcher …….. 1 for the whole class

Bicycle pump w/ pressure gauge …… 1 for the whole class

Duct tape …… 1-2 rolls

Mason string …….. 10 ft

Tennis balls …….. 1 per student

Manila folders …….. 1 per student

Vaseline …… 1 for the whole class

Preparation tips

Designate an open area outside where you can launch a bottle rocket. The area should NOT have tall buildings or trees around it, should NOT be covered and should be at least 50 x 50 ft. An ideal space is a soccer or football field.

Lay out the materials and tools in the classroom.

Challenge Description

Show a picture of a real rocket. Ask the students to list properties of a rocket. (nose cone, fins, etc.)

Go outside.

Test the rocket for its ability to fly straight by taping a string to its center of mass and twirling it in a circle around their head. (Show students how to find the center of mass of the rocket by attempting to balance the rocket on their finger.)

Ask...

"How can we make the rocket fly higher?" (weight in front, nose cone)

Add a tennis ball with tape to the rocket's nose and twirl it again.

Challenge students to go off and improve on their rocket so that it flies higher by adding weight and a nose cone.

Suggest experimenting with different weights (they don't have to use a tennis ball for weight) to maximize the rocket's launch height. (No need to do this if you don't have other materials at hand, but they could use water balloons, balloons with sand, etc.)

Below is a picture of a bottle rocket with fins and a nose cone.

Note: During testing, do not exceed 60 psi.

Troubleshooting

*How do I find a rocket's center of mass?

Put it on your finger and see where it balances.

Challenge #4: Don't Let Your Rocket Crash

30 – 60 min

Location: outside (or inside, with testing done outside)

Materials

Existing bottle rocket …… 1 per student

Rocket launcher …….. 1 for the whole class

Bicycle pump w/ pressure gauge …… 1 for the whole class

Duct tape …… 1-2 rolls

Mason string …….. 10 ft

Plastic bags …….. 1 per student

Vaseline …… 1 for the whole class

Preparation tips

Designate an open area outside where you can launch a bottle rocket. The area should NOT have tall buildings or trees around it, should NOT be covered and should be at least 50 x 50 ft. An ideal space is a soccer or football field.

Lay out the materials and tools in the classroom.

Challenge Description

Gather the students in a circle and choose a few rockets to inspect. Hold the rockets up and ask the students what they notice about the different designs.

(Note: You might notice that some of the rockets are crushed or the nose cone is crushed because of the hard landing)

> "How can we prevent the rocket from crushing when landing?"
> (parachute, shield)

Explain that a parachute creates a lot of air resistance because of the large area that's in contact with the air as it drops.

Challenge students to go off and improve on their rocket by adding a mechanism that will prevent crushing when landing. Encourage them to redesign and relaunch.

For parachutes you can supply string and plastic bags to deploy the parachute but other materials may be used if the instructor has them at hand.

Note: During testing, do not exceed 60 psi.

Troubleshooting

*How do I make a parachute out of a plastic bag and string?

You can tie one end of the string to the bag and one end either taped or tied to the bottle so that it deploys when it starts dropping. Don't use a lot of tape so that it can deploy. You need just enough tape to hold the plastic bag together during take-off.

*What other materials can I use for a parachute?

Fabrics and light flexible materials can be used. Plastic bags are cheap and readily available.

Challenge #5: Use your Rocket as a Launcher

30 – 60 min

Location: outside (or inside, with testing done outside)

Materials

Existing bottle rocket …… 1 per student

Rocket launcher …….. 1 for the whole class

Bicycle pump w/ pressure gauge …… 1 for the whole class

Duct tape …… 1-2 rolls

Mason string …….. 10 ft

Plastic cups ……... 1 per student

Vaseline …… 1 for the whole class

Other materials will be needed based on student interest, see below…….

Preparation tips

Designate an open area outside where you can launch a bottle rocket. The area should NOT have tall buildings or trees around it, should NOT be covered and should be at least 50 x 50 ft.

Challenge Description

Ideally this challenge would be introduced once Challenges #0-4 have been completed. This challenge opens the class up to creative ideas of what they can do with their water rocket now that they've optimized it.

Gather class together either in a circle or tight group so you can have a discussion. Place all the rockets in the middle of the group or on a table and let the students observe.

Ask them to say if they notice an interesting design and to explain why.

Ask...

> "Does anyone have any ideas of what we can do with these rockets now that we're done building them?"

Suggest using the rocket itself as a launcher by placing a cup on the nose cone and placing items you want to launch in the cup. (Note: Suggest to the kids that you can launch items by tying a ~50 ft. string to the rocket and tying it off somewhere on the ground near the rocket launcher. When you pressurize

the rocket and release it the string will tug on the rocket and the item placed in the cup will carry the momentum of the launch.)

> "What can we launch with a rocket that will make an interesting launch?" (Teacher's coffee, water balloon, little army men with parachutes…be creative!)

Send students off to modify their rocket so it can launch items. (NOTE: Make sure they check the item they want to launch with an adult)

Below is a picture of a rocket prepared to launch items.

Note: During testing, do not exceed 60 psi.

Troubleshooting

*Where can I tie the string?

You can tie one end on the bottle neck and one end can be tied under a rock, or on a stationary bottle filled with water on the ground.

Challenge #6: Rockets and High Speed Video

30 – 60 min

Location: outside (or inside, with testing done outside)

Materials

Existing bottle rocket …… 1 per student

Rocket launcher …….. 1 for the whole class

Bicycle pump w/ pressure gauge …… 1 for the whole class

High speed camera ……. 1 for the whole class

Vaseline …… 1 for the whole class

Preparation tips

Designate an open area outside where you can launch a bottle rocket. The area should NOT have tall buildings or trees around it, should NOT be covered and should be at least 50 x 50 ft.

Challenge Description

Ideally this challenge would be introduced once Challenges #0-4 have been completed. This challenge opens the class up to creative ideas of what they can do with their water rocket now that they've optimized it.

Gather class together either in a circle or tight group so you can have a discussion. Place all the rockets in the middle of the group or on a table and let the students observe.

Ask them to say if they notice an interesting design and to explain why.

Ask...

> "Does anyone have any ideas of what we can do with these rockets now that we're done building them?"

Suggest using a high-speed camera to take a video of a rocket launch.

> "What is a high-speed camera?"

Choose a rocket and take high-speed videos of it launching. (Note: If you place a ruler behind the bottle rocket, you can calculate it's speed at take off using the high speed video)

Note: During testing, do not exceed 60 psi.

Troubleshooting

*What if I don't have a high speed camera?

Sorry, this challenge is only done with a high-speed camera.

*Do I let the kids use the high speed camera?

NO. You or another adult should only use the high-speed camera. They are expensive.

Challenge #7: Point of View Rocket Launch

30 – 60 min

Location: outside (or inside, with testing done outside)

Materials

Existing bottle rocket …… 1 per student

Rocket launcher …….. 1 for the whole class

Bicycle pump w/ pressure gauge …… 1 for the whole class

Cell phone with video capability (not supplied by camp)..... 3 for the whole class

Vaseline …… 1 for the whole class

Preparation tips

Designate an open area outside where you can launch a bottle rocket. The area should NOT have tall buildings or trees around it, should NOT be covered and should be at least 50 x 50 ft.

Challenge Description

Ideally this challenge would be introduced once Challenges #0-4 have been completed. This challenge opens the class up to creative ideas of what they can do with their water rocket now that they've optimized it.

Gather class together either in a circle or tight group so you can have a discussion. Place all the rockets in the middle of the group or on a table and let the students observe.

Ask them to say if they notice an interesting design and to explain why.

Ask...

> "Does anyone have any ideas of what we can do with these rockets now that we're done building them?"

Suggest placing a camera on the rocket launcher to take a cool video or picture. (Note: You can place a camera with a lot of duct tape [to cushion the fall] to the side of a bottle rocket and record the launch. You can also place a camera with a time delay on the rocket so that when the rocket reaches its peak it takes a picture of the ground below it. Have any other thoughts on cool pictures or videos to take? Be creative!)

Split the class into 3 groups (1 instructor per group) and choose 3 consistently successful rockets (ideally with working parachutes) and have the students attach a cell phone to their rocket.

(Note: If parachute fails or if there's not enough cushioning the phone may be damaged permanently)

Gather the class and launch the rockets with cameras attached to them.

Note: During testing, do not exceed 60 psi.

Troubleshooting

*How do I know if I have enough cushioning on my phone?

You can use corrugated plastic and tape that around the phone to provide cushioning. To test it out, do drop tests from various heights before you do the actual rocket launch.

Challenge #8: Make the Launch More Interesting

30 – 60 min

Location: outside (or inside, with testing done outside)

Materials

Existing bottle rocket …… 1 per student

Rocket launcher …….. 1 for the whole class

Bicycle pump w/ pressure gauge …… 1 for the whole class

Food coloring ……..…… 1 bottle

Vaseline …… 1 for the whole class

Other materials will be needed based on student interest, see below…….

Preparation tips

Designate an open area outside where you can launch a bottle rocket. The area should NOT have tall buildings or trees around it, should NOT be covered and should be at least 50 x 50 ft.

Challenge Description

Ideally this challenge would be introduced once Challenges #0-4 have been completed. This challenge opens the class up to creative ideas of what they can do with their water rocket now that they've optimized it.

Gather class together either in a circle or tight group so you can have a discussion. Place all the rockets in the middle of the group or on a table and let the students observe.

Ask them to say if they notice an interesting design and to explain why.

Ask...

> "Does anyone have any ideas of what we can do with these rockets now that we're done building them?"

Suggestions:

- Add food coloring to the water and launch it
- Attach a simple LED circuit to the rocket and launch it (LEDs are not supplied)
- Add your own suggestions, be creative.

Note: During testing, do not exceed 60 psi.

Troubleshooting

Challenge #9: Create your own Rocket Launcher (Senior Camp only)

2 – 3 hrs

Location: outside or inside

Materials

Existing rocket launcher …….. 1 for the whole class

Note: Please see the Bottle Rockets Materials List document for the list of materials for Rocket Launchers

Preparation tips

Please see video HowToMakeABottleRocketLauncherFinal.mov to see how a launcher is assembled.

Lay out all the materials on tables in a designated area. Lay out the tools in another designated area. Before you start the challenge, make sure you show everyone what the materials are and what each tool is used for. Make sure you show everyone how to use the tools properly.

Challenge Description

Ideally this challenge would be introduced once Challenges #0-4 have been completed. This challenge allows the students to build their own rocket launcher.

Gather class together either in a circle or tight group so you can have a discussion. Place the rocket launcher in the middle of the group or on a table and let the students observe.

Ask them to say everything they observe about the design and to explain why it's designed the way it is.

List off things that the students would improve about the rocket launcher.

Split off students in groups of 4 and have them design and build a rocket launcher with their group.

(Note: Please see video on assembling a water rocket launcher)

(Note: There is an edit made to the video. Instead of using a napkin to secure the zip ties use rubber bands)

Troubleshooting

Challenge #10: (Be creative. Create your own challenge.)

Teacher creates his/her challenge **NOT** student.

Conclusion

10-30 min

Location: inside

(Note: Make sure you list all the learning goals on a board.)

To conclude the activity, gather the class in a circle in front of the board with the learning goals. Place all the bottle rockets and bottle rocket launcher(s) on a table in front of the classroom. Go through all the learning goals in a discussion style format letting the students know where each of the learning goals were applied. The learning goals should be mentioned throughout the activity as you go through each challenge so this should be more of a summary than long discussion about each learning goal.

Special Notes: The students can keep their bottle rockets but make sure you take back:

- ALL tools
- ALL Launcher Supplies
- Tennis balls
- Safety Glasses
- Mason String
- Food Coloring
- Vaseline

Additional Resources

Bottle Rockets

http://guides.machinescience.org/mod/book/view.php?id=834&chapterid=1201

Bottle Rocket Launcher

http://guides.machinescience.org/mod/book/view.php?id=833