Water Bottle Rockets

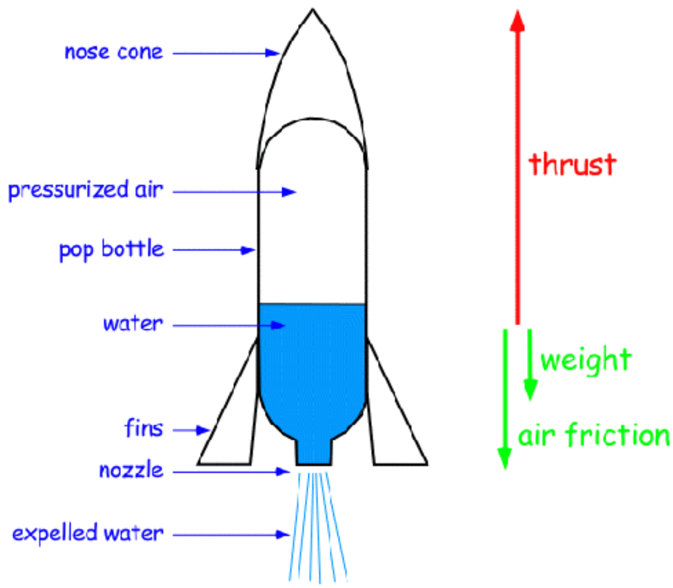
Materials (per school site, up to 20 students)

- Half a pack of Index Cards
- No more than 10-15 sheets of paper (may be supplied by schools)
- 3-4 empty large soda bottles, depending on size of group
- tape, scissors, markers (most likely supplied by schools)
- Pre-fabricated PVC launch stand

Teaching Plan:

Introduction (10min)

Discuss the science/design considerations/strategizing



- **Projectile motion**: Anytime you drop or throw something it follows the following path due to gravity.
- **Presssure**: The thrust needed to launch the rocket is given by the pressurized air and water within the rocket (soda bottle)
- **Stabilization and aerodynamics**: Using fins and nose cones to achieve different results
- **Engineering Design Process:** Ask, Imagine, Plan, Create, Improve
    - What things should you focus on when designing your rocket?
        - Fins (shape, number)
        - Nose Cone (how long/ angled/whether to even use a nose)
        - How much water to put into the rocket (think about more when testing the rockets outside)
    - How will you manage your time?
    - What will each team member work on?

Design and Build the Rockets (20 mins)

Provide each group of 4-5 students with one soda bottle
Provide paper (or index cards) for them to create fins/nose cones
Provide tape for attaching their decorations to their rocket
Walk around to assist or answer questions

Important: Ask each group questions while they're building and thinking. (ex: what would fins like those do for your rocket, what do you think would happen if you made your rocket without a nose cone, ect)

Test the Rockets Outside (15 mins)

Set up a launching station and a viewing station where everyone else must be behind and away from the launcher

Conclusion (10 mins)

Ask each group to explain how their rocket flew, why it flew the way it did, and what could be changed.

- What were some problems you ran into when designing your rockets? (Building Techniques)
- How did you manage your time? (Time Management)
- How did each team member contribute to each project? (Delegating tasks/working as a team)

Connecting to engineers (more topics to discuss)

- Modeling and simulation: In "real life" engineers use computers to design models to test their designs. Why would you want to test a rocket before building them and before using them to launch materials and people?

Mentors Scientific Background

Projectile motion: A projectile is any object that once projected or dropped continues in motion by its own inertia and is influenced only by the downward force of gravity. In the case of the water rockets, they are given an initial thrust by the expelled water, but once that direct force runs out; its path ideally follows that of projectile motion.

How the water bottle rocket works: Compressed air is added via a pump which creates a bubble that floats up through the water and then pressurizes the air volume in the top of the bottle. Once the bottle is released from the pump, the water is pushed out the nozzle by the compressed air. The bottle moves away from the water because of Newton's Third Law; for every action there is an equal and opposite reaction.

As the propellant (water) level in the rocket goes down, the center of mass initially moves backwards before finally moving forwards again as the propellant is depleted. This initial movement reduces stability and can to cause water rockets to start tumbling end over end, greatly decreasing the maximum speed and thus the length of glide. To lower the center of pressure and add stability, fins are added which bring the center of drag further back, well behind the center of mass at all times, ensuring stability.

Optional topic to discuss: The use of nose cones as crumple zones to ensure the safety of the rest of the rocket. Stabilizing fins cause the rocket to fly and fall nose-first. This way of falling gives the rocket a significantly higher velocity than it would have if it tumbled to the ground. This high speed impact is damaging to the rocket. This is noteworthy if the rocket has no parachute or other recovery system or it has one which malfunctions. This should be taken into account when thinking about the design of real rockets and the importance given in design to safety.