Community Outreach

As a part of NASA Grant, an engineering-focused school-level outreach event was planned, designed, and executed through the Idaho State Rocketry(ISR) Club to the 4th grade of Riverview Elementary School located at Shelly, ID.

- **Acknowledgments**

The outreach event - **'Water Rocket Design'** was designed by ISR Vice - President Shishir Khanal, the school search was done by ISR secretary Derek Andersen and the event planning was done by ISR president Derrick Likes. The materials for the event were provided by the ISU Department of Physics Outreach through ISU professor and Outreach Coordinator Dr. Steven L. Shropshire.

- **Objectives**
  - To familiarize the students with the physical principles associated with the rocket design.
  - To expose students to the design process.
  - To present students with an actual design constraint situation.

- **Structure of the Event**

The event was divided into 3 major sections:

1. **Demonstration Section:** This was the first part of the event which was about 25 mins long. The presenters used various demonstration materials to explain certain physics concepts and explained how those concepts can be used in the design of rockets.

2. **Design Section:** This was the second part of the event which was about 25 mins long. The basic components of the rockets were explained to the students and they were divided into groups of 4. After that, each group was provided with the design materials to build the rockets. At this point, the students started building the rockets and the presenters and the school teacher moved around the class to help the students understand the constraints of the design specific to their rockets.

3. **Launch Section:** This was the last section of the event. After the students completed building their rockets, they were taken out to the playground to launch the rockets they built.

- **Materials Used**

Presentation	Rocket Design
1. Toilet Paper Tug a. 2 Toilet Paper Rolls b. 2 metal rods c. 1 90^0 clamp d. 1 table Clamp **2. Skateboard Ball Throw** a. 1 skateboard b. 1 heavy ball **3. Clay on a Stick** a. 1 dowel with 1 lb mass attached on one side **4. Bicycle Wheel** a. 1 small Bicycle Wheel **5. Hoop Vs. Wheel Race** a. 1 Hoop b. 1 Wheel with the same mass as a hoop c. 1 Ramp **6. Rotating Stool** a. 1 stool b. 1 base to put the stool that is free to rotate around its center **7. Alcohol Rocket** a. 1 2l soda bottle b. 19 ml 95% Isopropyl Alcohol c. 1 Ramp d. 1 Ramp Base	**Per head Rocket:** 1. 1-2 2l bottles 2. 3 appropriately cut cardboard pieces 3. 1 scissor 4. 1 transparent tape 5. 1 Duct tape 6. 1 piece of a paper plate 7. 1 piece of clay or stone 8. 1 glue gun 9. 1.3 l water 10. 1 Water Rocket Launcher 11. 1 air compressor

- **Execution of the Event**
    - **Presentation Script**

Citation: Some sections of the script are used directly from the script of Forces and Motion show of ISU Physics Outreach[38]

Toilet Paper Tug

Two rolls of toilet paper, one full and the other almost gone, are placed on a rod so that they are free to rotate. Inertia is discussed. Inertia is a measure of how difficult it is to get something to move. We use weight and mass to measure inertia. The heavier something is, the more inertia it has, and the harder it is to get it to move. A very sharp or fast blow applied to something with a lot of inertia is more likely to break it rather than moving it. The same blow applied to something with less inertia is more likely to move it. It is very easy to rip off one or two squares of toilet paper with a quick jerk of one hand from a full roll without having it spin and unravel because of its large inertia. However, it is almost impossible to do this with a roll that is almost gone. Because of its low inertia, it is much easier to move. The larger rockets are harder to move than the lighter ones not because the earth pulls them differently(earth pulls both of them with the same force) but because of their inertia.

Skateboard Ball Throw

A student is asked to sit on the skateboard and throws a heavy ball at the presenter using his hands. The student with the skateboard moves backward. This is because when the student pushes the ball leaving his hands also pushes the person because of which the person moves backward. The student throws the heavier ball or if the student throws the ball faster he goes more backward than before. The rockets are propelled using the reaction forces of the hot gases exiting from the nozzle of the rockets.

Clay on a Stick

A 3 lb glob of clay is stuck on a 4' dowel, about 6" from one end. Students are asked which would be easier: to balance the dowel vertically with the clay near the top, or with the clay near the bottom. A volunteer is asked to try it both ways. It is far easier with the clay near the top. It is also much easier to wave the dowel back and forth with the ball of clay near your hand than with it near the end. Just as inertia is a measure of how difficult it is to get something to move, "rotational inertia" is a measure of how difficult it is to get something to rotate. The same amount of stuff near a pivot point has a much lower rotational inertia than the same stuff farther away. It is much easier to balance something with larger rotational inertia because gravity has a harder time tipping it over, giving the balancer more time to react when it starts to tip. The rockets have much static stability if the tip of their body is designed to be massive. Because of this, the nosecone of the rockets is always heavy.

Bicycle Wheel

Students are given a bicycle wheel with a weighted rim and handle on the axle. The wheel is much easier to move about when it is not spinning. The faster it spins, the harder it is to get it to change its motion. Also, students may be surprised that the wheel does not want to move in the directions they expect. This effect can be demonstrated dramatically by spinning the wheel vertically, holding one handle up by a long cord, and then letting go of the other handle. Instead of tipping over, the wheel will start to spin horizontally while staying vertical. The deep-space mission satellites are spun as they are propelled forward so that they are more stable in their path and do not easily change their direction.

Rotating Stool
As you spin on the stool with an arm sticking out, your arm moves faster than your elbow because it moves in a larger circle in the same amount of time. It also has more energy. If you bring your arm back in close to your body, you have to speed up to keep that energy. Student volunteers are asked to sit on a low-friction rotating stool and to hold weights out at arm's length. The students are spun slowly and told to move their arms in and out. The smaller their rotational inertia, the faster their spin, and vice versa. The wheel can be used to change the direction of rotation of the stool. If a student sits on the unrotated stool and starts spinning the wheel in one direction, the stool also starts rotating in the same direction. This idea is used in the gyroscopes which are used to change the direction of rockets in space.

Hoop Vs. Wheel Race
A thin metal hoop and a solid cylindrical wooden wheel are the same size and weight. They are both rolled down an incline from the same height in a race. The wheel will always win because it has lower rotational inertia. More of its weight is closer to its axis than with the hoop. It takes more energy to roll the hoop, so with the same energy, the wheel will roll faster. The orientation of the materials inside the rocket can also affect its rotation.

Alcohol Rocket
Another flashy action-reaction demonstration uses an alcohol rocket. A few ounces of isopropyl alcohol (95% or more works best) are poured into a 2l coke bottle with a 1/8" touch hole near the bottom of the bottle. With one hand capping the top, the bottle is shaken to fill it with the alcohol fumes. The bottle is placed on a slight incline, the hand was removed, and the cap side of the bottle is closed using a cork. A flame is brought to the pierced opening on the lateral side of the bottle as quickly as possible. The gas inside the bottle will burn, and expand rapidly from the heat and the combustion products. The pressure will force flaming gas backward out the opening at a high speed, which will in turn force the jug forward. This is spectacular with the lights out. This demonstration requires extreme caution. A fire extinguisher is necessary. The rocket will shoot flaming liquid out along with the gas. Students must be cautioned not to try this or any similar experiment on their own. A smaller but faster rocket can be made with a 2-liter pop bottle. Cover the hole with a finger as you shake 1/2 ounce of alcohol in the bottle. Plug the mouth with a cork and light the touch hole. The expanding, burning gas will blow out the cork and fling the rocket at a very high speed.

- **Design Instructions**

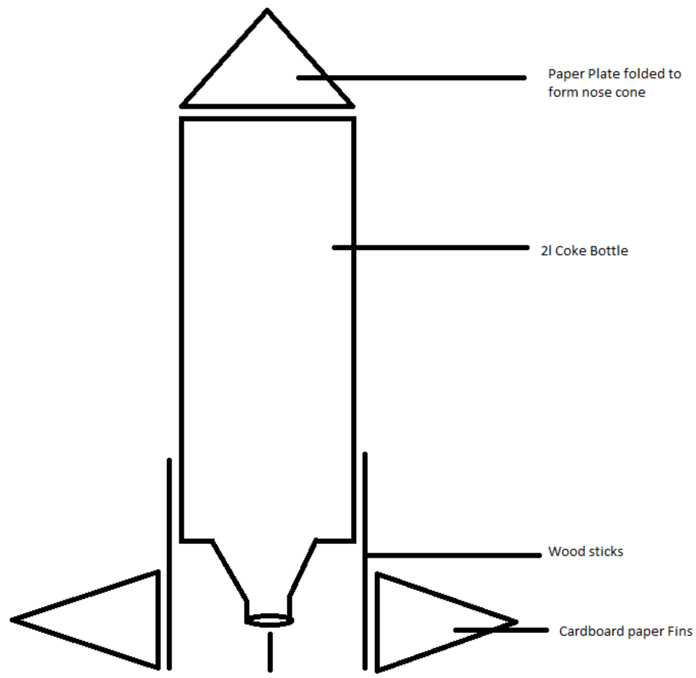


Fig: Schematic for Rocket Design

The general structure of the water rocket can be obtained by attaching the paper plate on top of the water rocket which is the base of the bottle and the wood attached with the fin on the cap side, both of which are taped onto the rocket. Following features can be achieved for the water rocket:

1. **Aerodynamics**: 2 bottles will be required for this. Cut ⅓ of the rocket from the cap side and tape it to the base side of another bottle. This makes the rocket smooth and aerodynamic.
2. **Static Stability:** Glue some clay or stone inside the nose cone. This will make the gravity take a longer time to mess up the stability of the rocket.
3. **Rotational Stability:** To rotate the flying rocket, the wings can be taped a little bit angled with the vertical onto the rocket. This will cause drag to exert some horizontal force on the rocket which will spin the rocket.
4. **Maximum Height: I**f the rocket has all of the above features using a minimal amount of tape, it will achieve optimal height.

- **Design Constraints**

During the design of the rocket, the students will experience the following constraints:

1. **Rigidity Vs. Inertia:** The rocket after its launch experiences variable drag forces. This will require the rocket to be rigid which can be achieved using more tapes. However, the more tape students use, the heavier their rocket becomes.
2. **Propulsive Thrust Vs. Inertia:** The water used in the water helps to regulate the pressure to distribute thrust over time. However, the more water we use the more inertia we gain. We need to use the amount of water such that the water is completely used up when the excess pressure is used up.
3. **Rotation or Lateral push:** The tilting of the fins gives the rocket a lateral push to spin. However, The irregular angling of the fins gives variable lateral force which can cause the rocket to be unstable and deviate from its trajectory.

- **Rocket Launch**

The rocket was then filled almost half with the water and then taken outside to be launched. It was then put onto the launcher and pressurized to 120 psi. The rocket launched in the air students were asked to cheer for their team.

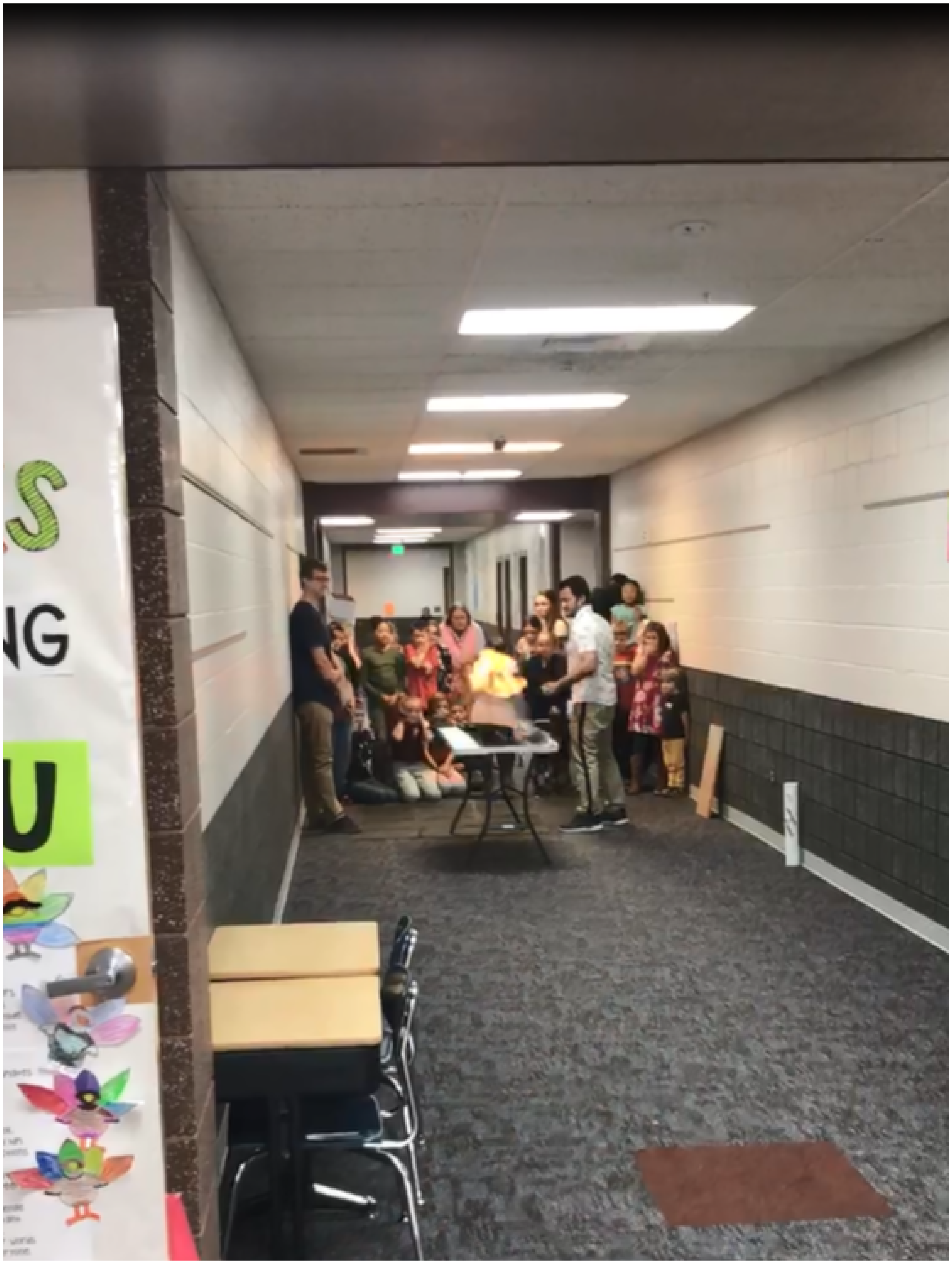
Pictures of the event:

The pictures of the event are courtesy of Derrick Likes and are put in Appendices A1 - A5.

Appendix:

A1: Shishir Khanal giving a presentation to the class

A2: Shishir Khanal performing the Alcohol Rocket Demonstration



A3: Shishir Khanal discussing the Rocket Design Process

A4: Derrick Likes and Shishir Khanal demonstrating Hoop Vs. Wheel Race

A5: Derek Anderson pressurizing the rocket

A7: Fourth graders of Riverview Elementary School with their Rockets