6. Designing Experiments
Build Knowledge

INTRODUCTION

What Students Do in This Activity

Students share their hypotheses about factors that influence performance of the JetToys. They make lists of factors they can and cannot control. Controlled experiments are introduced and discussed. Students suggest variables to test and review the data sheets and graphs they will use to record their experiments.

Rationale

By now students have built reliable vehicles for testing and are familiar with changing nozzle sizes and adding weights. They may have a sense of how the vehicles behave with different nozzle sizes and weights, but do not have much data to support their hypotheses. After conducting controlled experiments and reviewing the data, students will be able to draw conclusions that help them design vehicles which meet specific performance requirements as part of the class fleet.

Time

1 class session

Materials

for each design team:

- its completed JetToy Data Table 1 from Activity 5
- its JetToy chassis, with wheels attached
- three balloon motors (one of each nozzle size)
- 1 weight (nine pennies)

for each student:

- JetToy Data Table 2, Reproducible Master 11
- JetToy Graph, Reproducible Master 12

for the teacher:

- a transparency of JetToy Data Table 2, Reproducible Master 11 (optional)
- overhead projector (optional)

CLASSROOM ACTIVITY

Presenting the Activity

Explain to students that they now have some information about how their vehicles perform when set up in a variety of ways. To design a fleet of vehicles that meet the requirements of EarthToy Designs, they will need accurate information about how the different configurations affect the JetToy's performance. To get this information, the class will do formal testing of their vehicles.

Testing JetToy Characteristics

Ask students to suggest which performance characteristics they think should be tested more carefully. Make a list of these on the board. Students' suggestions will probably include nozzle size, nozzle position, and amount of added weight.

To set up formal tests, the class needs to review the knowledge design teams have about the effects of the characteristics they have been working with. Understanding both the effects of nozzle size and the ability to carry weight is important to satisfying the requirements of EarthToy Designs: that the class fleet of JetToys shows a variety of performance characteristics.

Volunteer Tip:

An industry volunteer can share experiences in testing, talk about how testing is used in industry, and explain why testing is important in developing reliable products.

Nozzle Size

Ask the students to share their vehicles' performance results from testing different nozzle sizes.

- What observations did you make about the relationships between different nozzle size and distance, speed, time, and rolling straight?
- What conclusions can you draw about the effects of nozzle size on performance?

Teacher Tip:

Refer to the Science Notes in the Introduction to this challenge for more information about the effects of nozzle size on performance and the ability to carry weight.

Ask students to support their conclusions by referring to the data they recorded. Write these hypotheses on the board. Ask students to agree or disagree and explain why.

Weight Capacity

Ask the students what differences they noticed in how their vehicles performed with the weights added.

- What conclusions can you draw about characteristics that seem to help a vehicle carry weight?
- How did the nozzle size, in particular, affect your vehicles' ability to carry weight?

Students will observe that the large nozzle seems to carry the weight more easily. Add these hypotheses to the list on the board.

Introducing Controlled Experiments

Discuss how to set up a series of tests that would provide data on the effects of nozzle size and added weight. Ask students what they would expect to happen in situations like the following:

A 3/16-inch nozzle and two weights

A 1/2-inch nozzle and two weights

A 5/16-inch nozzle and zero weights

- In which case would the vehicle travel the farthest distance?
- In which case would the vehicle travel the longest time?

Students may take some calculated guesses but probably will realize they do not have enough information to make an accurate prediction.

- What could you do to predict the vehicles' behavior more accurately and with greater confidence?

Ask the class to name features that affect the performance of the vehicle. Students will probably make these suggestions:

- The size of the nozzle
- The number of weights
- The amount of air in the balloon

Write students' suggestions on the board, or on chart paper. Discuss how the class can test these features more carefully.

- Which of these features can you test? How?

Students will recognize that they can test all of the features listed above. These features are considered *variables* because the students can vary their settings, or values, in order to test their effect on the performance of a vehicle. For example, students can inflate the balloon to any size they want, which will affect the distance the vehicle goes.

Inflating the Balloon to a Standard Size

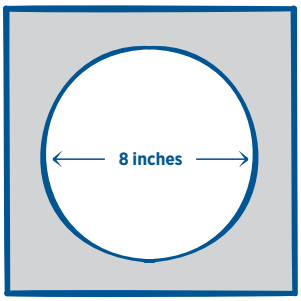
Discuss why students need to keep the balloon inflated at the same amount for each test.

- If the balloon is inflated at different amounts for different tests will the results be reliable?

See if students can brainstorm some ways to put the same amount of air in the balloon for each test. One way is to use the same number of pump strokes each time a balloon is inflated. This puts the same volume of air into the balloon each time. Another way is to make a balloon inflation guide. Here are two types of balloon inflation guides:

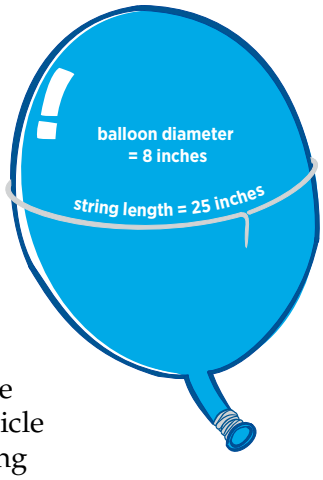
1. **Hole template method:**

   Cut a hole of the desired size out of stiff paper. An 8-inch diameter works well for 9-inch balloons. To use the template, students inflate their balloon until the widest part of the balloon just fits in this hole.



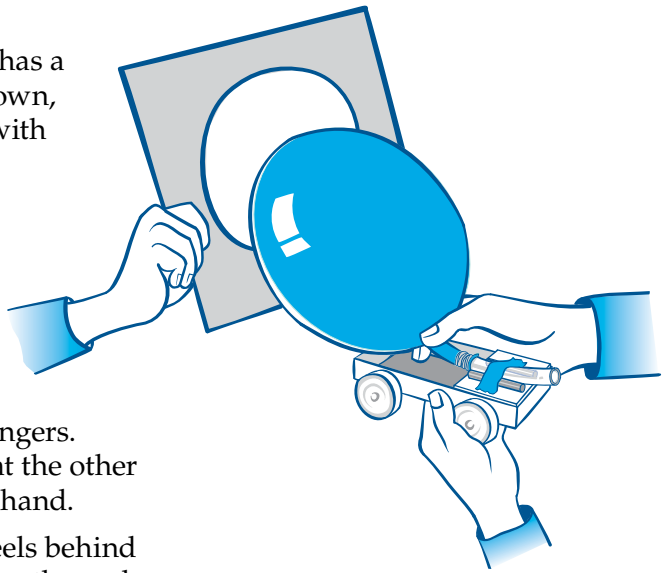
2. **String method:**

   Cut a piece of string to the desired circumference. Hold it around the widest part of the balloon. When the ends of the string just touch, the balloon is ready. The circumference is pi × the diameter. You can have students calculate the string length required. The circumference of an 8-inch balloon is about 25 inches.



Here is a suggested procedure for inflating the balloon to a standard size and setting the vehicle on the ground ready to run, without air leaking out. Students will need to practice this before doing formal testing.

1. Attach the nozzle securely to the vehicle. If the nozzle has a curve to it, make sure the nozzle curves either up or down, not to the left or right. Center the nozzle and fasten it with tape or pipe cleaners, or by some other means.
2. Hold the vehicle by the body, not the wheels, and inflate the balloon. Inflate the balloon slightly larger than you need. Use a balloon inflation guide and deflate as needed until the balloon is the desired size.
3. Seal the end of the nozzle shut with your thumb and hold the nozzle between your index and middle fingers. Alternatively, seal the nozzle by pinching the balloon at the other end of the nozzle. Support the vehicle with your other hand.
4. Carefully set the vehicle on the starting line, front wheels behind the line. Hold the vehicle very lightly while maintaining the seal.
5. Release the nozzle seal and let go of the nozzle or any other part of the vehicle at the exact same time.



Understanding Constant Values

In a controlled experiment, all of the variables are held constant except for the characteristic being tested. For example, if you want to test the effect of adding weights to the vehicle, you would choose one nozzle size, inflate the balloon to the same size each time, and not make any other changes to the vehicle. On each trial run you would change only the number of weights carried.

Brainstorm with students why they need to keep values not being tested the same for each test. If more than one property varies in a given set of experiments, it's hard to know which property is responsible for variations in the vehicle's performance. The results could be due to either variable, or to a combination of the variables acting together. This makes it hard to assess the impact of a single variable on the vehicle's performance. Students must make sure that any characteristic that might affect the vehicle's performance is held constant.

Ask students:

- Why is it important to investigate one variable at a time?
- If you changed two variables at a time in an experiment, what could you say about the reason for the results you observed?
- How might you design an experiment to test the effect of each individual variable?
- Why is it important not to change the characteristics that are not being tested?

Nozzle Size (inches)	0 Weights Carried		1 Weight Carried	
	distance	time	distance	time
$\frac{3}{16}$	a. 7 meters	13 seconds	b.	
$\frac{5}{16}$	c.		d.	
$\frac{1}{2}$	e.		f.	

Using JetToy Data Table 2

Display a transparency of JetToy Data Table 2, Reproducible Master 11, or distribute a copy to each student. Explain how teams will enter data. The table is set up so that each design team does a total of 18 trials with its vehicle: three trials of each for all three nozzle sizes for 0 and 1 weight. The average of the three trials should be entered into the table.

For each trial, design teams will record the distance the vehicle traveled and the time the vehicle traveled in the appropriate column.

Discuss the order in which design teams should do the experiments. Each design team should choose a nozzle size, then test their vehicle with and without weight carried, then change nozzles.

Teacher Tip:

If your students are familiar with finding the mean (or average) to summarize data, have them do three trials for each test, record the three distances and times in their design logs, then find the mean distance. They can enter the mean distances on JetToy Data Table 2. Allow extra time for students to perform the trials.

Graphing Data

Explain that after each design team has completed its data table, it will graph its six distance numbers.

Display a transparency of JetToy Graph, Reproducible Master 12, or draw a sketch of it on the board. Show students how they will plot three sample data points for the small nozzle. Suppose the vehicle went three meters with zero weights added. To plot this point, demonstrate how to find the zero on the X axis (representing 0 weights). Go up to the three (representing 3 meters) on the Y axis and mark a point.

Explain that because students will be plotting two points for each of the three nozzles, the class needs to distinguish the graph points for the two amounts of weight. Ask students to suggest ways to distinguish the data.

One way is to use different symbols to distinguish the points. A circle will show the points for the 3/16-inch nozzle. Draw a small circle around the point to show that it represents a test of the 3/16-inch nozzle. Now plot a point for the 3/16-inch nozzle with one weight in the same way.

Now show students how to plot a data point for the 5/16-inch nozzle and zero weights. To distinguish it from the other zero weight point, draw a square around the point. Have students plot the data points for the 5/16-inch nozzle and one weight. Connect the points with line segments.

Next, have students plot data points representing distances for the 1/2-inch nozzle and put a triangle around the points. Connect these points with line segments.

Discuss how the use of the circle, square, and triangle distinguish the data points and allow you to draw a line connecting the points for each nozzle size. Students can then compare the nozzles with one another as well as looking for trends in the distance traveled as weight is added.

Team Members_____ Date _____

JETTOY DATA TABLE 2

Nozzle Size (inches)	0 Weights Carried		1 Weight Carried	
	distance	time	distance	time
$\frac{3}{16}$				
$\frac{5}{16}$				
$\frac{1}{2}$				

Team Members_____ Date _____

JETTOY GRAPH