Exploring Whirligigs

Grade Level:	**Total Time Required:**
3 (Fair Test Investigations) 4 (Fair Test Investigations and Drag and Speed)	Three to five 30 minute class sessions

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Original source: This lesson is an adaptation of a lesson developed by *Project-Based Inquiry Science (PBIS)* at http://its-about-time.com/pbis/pbis.html

Lesson Objectives: In this lesson, students will participate in an inquiry-based science lesson.

Students will be able to:

1. Make predictions and formulate testable questions.
2. Plan, design, and carry a fair test investigation.
3. Perform investigations using appropriate tools (i.e., stopwatch).
4. Use measurement skills and apply appropriate units (i.e., height) when collecting data.
5. Test predictions with multiple trials.
6. Keep accurate records in a notebook during investigations and communicate findings to others using graphs, charts, maps and models through oral and written reports.
7. Identify simple patterns in data and propose explanations to account for the patterns.
8. Compare the results of an investigation with the prediction.

Indiana Standards:

4.PS.4 Describe and investigate the different ways in which energy can be generated and/or converted from one form of energy to another form of energy.

4.PS.2 Investigate the relationship of the speed of an object to the energy of that object.

3-5.E.3 Construct and perform fair investigations in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

Next Generation Science Standards: Discipline Core Ideas 3-5.ETS1-1 Identify a simple problem with the design of an object that reflects a need or a want. Include criteria for success and constraints on materials, time, or cost. Science/Engineering Practices 1. Asking questions (for science) and defining problems (for engineering) 6. Constructing explanations (for science) and designing solutions (for engineering) 7. Engaging in argument from evidence Crosscutting Concepts 2. Cause and effect: Mechanism and explanation.
Common Core Mathematics: Not applicable.
Common Core English and Language Arts: Not applicable.

Concepts and Vocabulary

Term	***Defined by a scientist or engineer***	***Defined by a student***
Force	Any push or pull	A push against something
Friction	The resistance that one surface or object encounters when moving over another	Rubbing between two objects or surfaces Can get hot
Gravity	Gravity is a force of attraction between two objects. All objects with mass have gravity. Gravity acts like a magnet - pulling objects together. The Earth has gravity. Gravity holds everything close to this planet.	Pull to the Earth
Air resistance	Also called "drag force" This force is a resistive force; opposing the motion of an object This force is due to friction between the object the fluid (gas or liquid) that it travels in.	Friction in the air
Thrust	Thrust is the force which moves an aircraft through the air. Thrust is used to overcome the drag of an airplane, and to overcome the weight of a rocket. Thrust is generated by the engines of the aircraft through some kind of propulsion system.	A push or shove forward
Lift	Lift is a mechanical force. It is generated by the interaction and contact of a solid body with a fluid (liquid or gas).	To pick up, boost, or kick

Equipment, Materials, and Tools

Materials		
Copies of the Whirligig Template	Cardstock	Overhead Transparencies
Tape	Paper clips (small)	One textbook
8 flat-bottom coffee filters for demonstration		

Tools		
Scissors	Metric ruler or meter stick or measuring tape	Stopwatch

Safety Guidelines: Monitor students when using scissors and while dropping Whirligigs from specific heights.

Science Content - Basics

Earth's gravity pulls things toward Earth. Students should be able to describe how gravity affects the motion of the whirligig.

Drag or air resistance is a force opposing the motion of an object moving through air. Students should be able to describe what causes air resistance or drag.

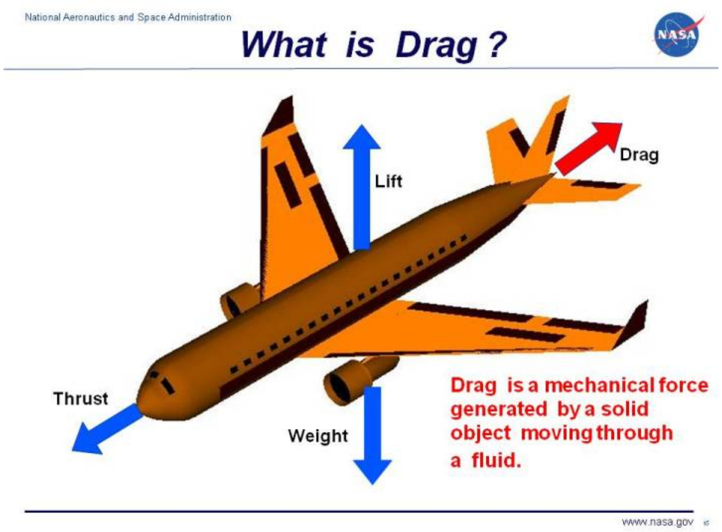

Image from https://www.grc.nasa.gov/WWW/k-12/airplane/drag1.html

Lesson Plan #1
Guiding Question(s) – How do things fall?
What affects how an object falls toward the Earth?

Time: Two 30 minute class sessions

Students are first introduced to the challenge of explaining how things fall. They predict, observe, and compare three demonstrations of falling objects with the same and different weights and surface areas. The three demonstrations are designed to build upon students' existing knowledge and/or conceptions of how things fall. You may use one, two or all three demonstrations to gather students' prior ideas.

Note: *Try the three demonstrations before you do them in class to make sure the objects fall as expected. You should make sure there are no drafts in the room by closing doors and windows and by performing the demonstrations away from blowing air vents. You should also make sure you drop the objects high enough from the ground so that there is a noticeable difference in how they fall that students can observe.*

1. <u>Demonstration 1:</u>

   The 1st demonstration consists of dropping a book and piece of paper from the same height at the same time. The paper and book should be parallel with the floor when you drop them. The paper should sway and fall more slowly than the book because it reaches its terminal speed more quickly than the book. (At the very end of this section you may want to show that the paper and book fall about the same rate when the paper is crumpled into a ball.)

   1. Ask students to make a prediction prior to performing the demonstration.
      - *What do you think will happen? Why?*
      - *How do you know (based on what prior knowledge or experience?)*

   2. Conduct the demonstration. Ask:
      - *What did you observe?*

2. <u>Demonstration 2:</u>

   The 2nd demonstration consists of dropping a stack of seven coffee filters and a single coffee filter at the same time and from the same height. Both should be dropped with the bottom facing the floor and the "cup" part facing the ceiling as shown. The seven filters should hit the ground first.

   1. Ask students to make a prediction prior to performing the demonstration.
      - *What do you think will happen? Why?*
      - *How do you know (based on what prior knowledge or experience?)*

   2. Conduct the demonstration. Ask:

- *What did you observe?*

3. <u>Demonstration 3:</u>
   For the 3rd demonstration you should tape together the rims of seven coffee filters into a flower pattern. Make sure each filter is connected to the center filter and to its adjacent filter, placing the tape at the midpoints of the adjoining arcs that the rims form. Drop the single filter and floral-pattern filters at the same time from the same height. Be careful to make sure they are at the same height — the floral pattern droops a little — line up the bottom of the middle filter with the bottom of the single filter. The single filter should reach the ground first. (You may also want to drop seven stacked filters against the floral pattern. The seven stacked filters should reach the ground first.)

   1. Ask students to make a prediction prior to performing the demonstration.
      - *What do you think will happen? Why?*
      - *How do you know (based on what prior knowledge or experience?)*
      - *Which had more collisions with air particles and had to move more air out of the way? (floral pattern)*

   2. Conduct the demonstration. Ask:
      - *What did you observe?*

4. Engage students in a discussion. Record students' ideas on the board or chart paper. Title the notes as "What we think we know about falling objects?" Ask:
   - *What do you think affects how slowly or how fast an object falls towards Earth? Why?*

   Summarize with students the following:

   "So far we have learned that:
   - *An object falls through the air toward the Earth and it collides with the particles in the air. These collisions cause an upward force on the object. Air resistance pushes opposite to its downward motion.*
   - *The more surface area an object has, the more air resistance it will have, and the slower it will fall. In other words, it will take a longer time to fall.*
   - *When mass is added to the object, there is an increase in the pull between Earth and the object. It will take less time for the object to reach the ground."*

   Make sure students know the following ideas before continuing.
   - Things fall because gravity pulls them toward Earth.
   - Objects moving through air collide with air molecules, causing a push on the object opposite to the direction it is moving in.
   - Adding mass to an object, results in the object falling more quickly (less time).
   - Increasing the surface area results in the object falling more slowly (more time).

5. Explain to students that they will work in small teams to conduct an investigation. In this investigation, students will create a whirligig pattern that fits on the back of a cereal box and that when constructed, falls as slowly as possible.

A cereal company wants to create a new whirligig that will fall more slowly than the one they have been using. They think that would be more fun.

Your challenge is to determine how to make a whirligig that will fall more slowly than the current one.

6. Explain to students what a whirligig is by showing them pictures or video. A whirligig is an object that spins or whirls, or has at least one member that spins or whirls.

   Examples include:
   - pinwheels
   - comic weathervanes
   - spinners

   

   Show them an example of the whirligig they will experiment with in class. (See PDF for Whirligig Template).

7. Encourage students to make their own observations of the performance of a whirligig. Give students their own templates (either have them cut out and assembled already or have students cut them out and assemble) and encourage them to experiment with the whirligig. Encourage students to try to drop the whirligig from different heights and to make observations of its performance. Instruct students to record the time it takes for the whirligig to fall at a specific height.

   Ask:
   - *What do you think happens when a whirligig falls?*
   - *How slowly does it fall?*
   - *When does the whirligig start spinning and how fast?*
   - *Does the whirligig always spin in the same direction?*
   - *Is the path of descent straight or wavy?*
   - *Does the whirligig stay vertical when falling or not?*

8. Encourage students to brainstorm their ideas about how to address their challenge:

   Your challenge is to determine how to make a whirligig that will fall more slowly than the current one.

9. Instruct students to record their ideas.

Lesson Plan #2
Guiding Question – How can we design a slow-falling whirligig?

Time: Two to three 30 minute class sessions

Procedure:

1. Divide the class into small teams. Assign each team one variable to investigate. Students may investigate one of the following independent variables:
   - Blade length (short, standard, and long)
   - Number of paper clips (0, 1, 2)
   - Scale (size) (half, standard, double) *[optional]*
   - Type of paper (transparency, standard, thick) *[optional]*

   Suggestion: Divide the class into two larger groups: blade length vs. number of paper clips.

2. Review with students the key components to a good fair test investigation.

Component	***Description***	***Whirligig application***
Problem statement	*Students record the question that is guiding their investigation*	*How can we make a whirligig that will fall more slowly than the current one?*
Prediction	*Students make predictions about the performance of their whirligig.*	(Prediction is made based on the independent variable) *The larger the blade, the slower it will fall.*
Independent variable	*The factor or variable you are purposefully changing or manipulating.*	Blade length Mass of the whirligig (number of paper clips)
Dependent variable	*How you will measure this change.*	Time (in seconds)
Control	*The sample that is untreated.*	The standard size whirligig
Repeated trials:	*Multiple tests are conducted.*	3 or more trials

Ask the students:
- *Which part of the whirligig will you be changing in your experiment?*
- *Which variable will you manipulate (change) in your experiment to test the effects of that whirligig part?*
- *What conditions and procedures will you keep the same (hold constant or control) in your experiment?*
- *What will you measure?*
- *How many trials will you do for each value of your manipulated variable?*

Note: Be sure the class decides the height all whirligigs will be dropped so that each team is following the same procedure. Also encourage students to determine the number of repeated trials. Lastly, be sure students determine how they will organize and record their results.

An example of a possible lab sheet is provided (see last page).

3. Once teams have been assigned and students have prepared their procedures and data tables, encourage students to begin testing. Allow students up to 20 minutes for testing.

Lesson Plan #3
Guiding Question – Which design makes the slow-falling whirligig?

Time: One 30 minute class session

Procedure:

1. Encourage students to share their results. Ask:
    - *What did you observe?*
    - *Did you encounter any problems or challenging when testing?*
    - *How did you address the problem?*
    - *Looking at our data tables (either individual or whole class table), what patterns do you see? In other words, as the blade size increased, what happens to the time? As the number of paper clips increases, what happens to the time?*
    - *Which type of whirligig fell more slowly than the current one?*

    Remind students of the demonstration you did in the first lesson where you dropped seven stacked coffee filters and seven filters in a floral pattern. Ask students which they thought had more collisions with air particles and had to move more air out of the way: the floral pattern. Ask which felt a greater push upward from air resistance (*The floral pattern*.)

    Ask students what they think this means for the whirligig blades? (*Longer blades have more surface area so more collisions occur with the air*.) Students should describe that when the blades get longer there is more surface for the air particles to collide with, causing a greater push upwards on the whirligig. Students should also include their observations from their experiment. As the blade length (surface) increased, the time it took to reach Earth decreased. Guide students by asking them questions about how the air and whirligig interact as the whirligig falls through the air.

    Discuss with the class that increasing the number of paper clips increases the mass of the whirligig and hence, the force of gravity acting on the whirligig.

    Say: **"***When you add paper clips to the whirligigs you are increasing the whirligig's mass. What happens when the mass gets bigger? (There is a greater pull between Earth and the whirligig.)* **"***How does this affect the time of flight? If we were to drop a whirligig with one paperclip and another whirligig with five paper clips from the same height in an air-free environment, they would reach the ground at the same time. The force due to gravity pulls more strongly on the more massive whirligig, but it does so in such a way that the rate at which the two whirligigs fall is the same. However, we did not drop the whirligig in an air-free environment: our whirligigs have air in the way of their fall. The air resistance acting on the whirligig can only get as big as the force of gravity and it depends on the surface area and the speed of the object. The faster the object goes, the greater the push from air resistance acting on it. When we add more mass to the whirligig, increasing the* *gravitational force between the whirligig and Earth, we also increase how big the air resistance can get. This allows the whirligig more time to speed up before it reaches its maximum value and results in the whirligig falling more quickly to the ground than when it has a smaller mass. The important part to remember here, is that it is not just the mass of the object but also the air it is moving through that affects how fast it falls.*"

Make sure students know the following ideas before continuing.

- Things fall because gravity pulls them toward Earth.
- Objects moving through air collide with air molecules, causing a push on the object opposite to the direction it is moving in.
- Adding paper clips to the whirligig resulting in the whirligig falling more quickly (less time).
- Adding blade length increases the surface area resulting in the object falling more slowly (more time).

2. Remind students that they now have evidence and science knowledge about what happens when a whirligig falls. Tell students that when they make a recommendation to the cereal company they will need to explain how to make a slow-falling whirligig. The cereal company will want a scientific explanation.

   Say: "*Now that you have some evidence from your investigations and you know more about how things fall, you need to explain to the cereal company how to make a slow-falling whirligig. They will want to know why your recommendation will make a whirligig fall slowly. They will want a scientific explanation.* "

   Encourage students to prepare their recommendations to the cereal company. Instruct students to read aloud their recommendations.

3. As a final evaluation, instruct students to respond to the following questions either in writing or aloud in class:
   - *What did you learn from your experiments?*
   - *What is the evidence that supports that idea?*
   - *What did you learn about gravity/air resistance?*
   - *What did you learn about how gravity/air resistance affects the whirligig?*

   Claim: The force of gravity between Earth and the whirligig causes the whirligig to fall to Earth.
   Evidence: This is supported by accepted science knowledge and our everyday experiences.

   Claim: Objects fall toward Earth.
   Evidence: We learned that mass attracts mass and that objects with mass are attracted to the Earth, this is called the force due to gravity. We also observe this in our daily experience when dropped objects (such as the whirligig) fall toward Earth.

   Claim: Increasing the number of paper clips decreases the time of fall.

Evidence: Experimental data showing this trend and accepted science knowledge. (Science knowledge = increasing gravitational force results in a greater maximum value for the drag force resulting in reaching its maximum value and a higher terminal speed in a longer amount of time.)

Claim: Increasing blade length increases the time it takes the whirligig to fall.
Evidence: Experimental data showing this trend and accepted science knowledge. (Science knowledge, increasing surface area causes drag force to reach its maximum value.

Assessment

The following are possible sources of formative and summative assessment:

Formative:

- Check students' lab notebooks or lab sheets for completion
- Engage students in a class discussion about the key elements of a fair test investigation.

Summative:

- Collect students' lab sheets and assess their final reports based on: 1) completion of responses; 2) organization of data; and 3) use of evidence-base claims in their conclusions
- Encourage students to prepare reflections in their experiences with working on a team (see reflection questions in last lesson).

Lesson Extensions and Resources

Activity Extensions:

Resources:

Provides a detailed overview of Whirligig Science related lessons and lesson plans: https://its-about-time.com/pdfs/div/3_4.pdf

Crismond, D., Soobyiah, M., & Cain, R. (2013). Taking engineering out for a spin. *Science and Children*, 52-57.

Whirligig Lab Sheet

The problem I am investigating is: ____

____

My prediction is: ____

____

The independent variable is: (circle one)

Blade length   Number of paper clips

The dependent variable is: ____

My Results Table:

Trial	Time the whirligig travelled (in seconds)		
	Blade length (short) Number of clips (0)	Blade length (standard) Number of clips (1)	Blade length (long) Number of clips (2)
1			
2			
3			
Average			

I can conclude that: ____

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