Science and Innovation

A Boeing/Teaching Channel Partnership

SPY GLIDERS

Teacher Handbook

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Spy Gliders

Day 2: How Planes Fly

Grade Level	Middle School
Lesson Length	One 50-minute session

Lesson Overview

In this lesson, students investigate the forces involved in flight. Students visit four different stations, each featuring a different investigation designed to help students make sense of the forces involved in flight. Students create a series of models to explain their developing ideas about flight.

After developing initial ideas about the forces involved in flight, students design prototype airplanes to test their ideas. Students investigate the features of gliders to learn what makes them stable for long distances. They test paper planes to see which ones perform the best and look for design similarities among the successful tests. Students then use the four forces of flight—lift, drag, thrust, and gravity—to better explain their test flight observations. This lesson reinforces essential pieces of the engineering design process, especially testing, making observations, and recording data.

Connecting to the Next Generation Science Standards

In this lesson, students make progress toward developing understanding across the following three dimensions:

- Science and Engineering Practices: Developing and Using Models, Analyzing and Interpreting Data
- Disciplinary Core Ideas: ETS1.B Developing Possible Solutions, ETS1.C Optimizing the Design Solution, PS2.A Force and Motion
- Crosscutting Concepts: Cause and Effect

In the following table, the specific components addressed in this lesson are underlined and italicized. The specific connections to classroom activity are stated.

Performance Expectations

This lesson contributes toward building understanding of the following *engineering* performance expectations:

MS-ETS1-3. *Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.*

MS-ETS1-4. *Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.*

This lesson contributes toward building understanding of the following *physical science* performance expectations:

MS-PS2-2. Plan an investigation to provide evidence that *the change in an object's motion depends on the sum of the forces on the object* and the mass of the object.

Specific Connections to Classroom Activity

In this lesson, students develop an initial understanding of the forces involved in flight. Using their knowledge of the forces involved in flight, students create and test a prototype glider using paper airplanes. They collect and compare data from the tests and revise their gliders accordingly. As students experiment with glider designs, they consider the ways that thrust, lift, gravity, and drag apply force on the airplane. This sets students up to begin thinking about what might happen if they add weight to their glider.

Dimension	NGSS Element	Connections to Classroom Activity
Science and Engineering Practices	**Developing and Using Models** • *Develop a model to predict and/or describe phenomena.* • *Develop a model to generate data to test ideas about designed systems,* including those representing inputs and outputs. **Analyzing and Interpreting Data** • *Analyze and interpret data to determine similarities and differences in findings.*	In this lesson, students create a series of models to describe the phenomenon of flight. In addition, students use a paper airplane model to test glider designs. Students modify their models to optimize performance. Students test a variety of glider designs to determine the best characteristics of each design. During the tests, students collect qualitative and quantitative data and compare their findings.
Disciplinary Core Ideas	**ETS1.B: Developing Possible Solutions** • *A solution needs to be tested, and then modified on the basis of the test results, in order to improve it.* • *Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.* • *Models of all kinds are important for testing solutions.* **ETS1.C: Optimizing the Design Solution** • *Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design.* • *The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.* **PS2.A: Force and Motion** • *The motion of an object is determined by the sum of the forces acting on it*; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in	Students develop and test several glider designs. Students work to optimize their designs based on data from their tests. As students test glider designs, they should realize that some gliders do not perform well. In later lessons, students should find that these same designs work well when weight is added. This lesson sets students up for this understanding. In previous lessons (not included in this module), students should have already developed the idea that the motion of an object is determined by the sum of the forces acting on it. In this lesson, students develop an idea of the forces acting on an airplane to keep it in the air.

	motion. For any given object, a larger force causes a larger change in motion.	
Crosscutting Concepts	**Cause and Effect** • *Cause and effect relationships may be used to predict phenomena in natural or designed systems.*	Students recognize that changes to their airplanes affect the distances they travel.

Basic Teacher Preparation

Students should work in their design teams for this lesson. Prior to the lesson, set up four stations for student investigations. If possible, create the paper helicopters prior to class to save time. Directions for folding the helicopters can be found at Paper Helicopters.

Web Resources

- Paper Helicopters [Web Link]
- Talk Science Primer [Web Link]

Four Stations

1. Station #1: Tent with a Straw—Enough straws for each student, 5 or 6 pieces of 20x13cm paper
2. Station #2: Ball and Straw—Enough straws for each student, 5 or 6 ping pong balls
3. Station #3: Paper Paper—6 to 8 pieces of notebook paper
4. Station #4: Helicopters—5 or 6 premade paper helicopters

Preview the required videos and have plenty of paper available for the paper airplanes. Review the Talk Science Primer, to help you prepare to lead the whole class discussion.

Refer to the Spy Gliders Student Handbook ahead of time so you can address any questions students might have. All documents used on Day 2 are on pages 4 through 10 in the Spy Gliders Student Handbook. The documents used in this lesson are:

- 2.1: How Planes Fly: Initial Model (page 4)
- 2.2: How Objects Fly: Stations (pages 5 and 6)
- 2.3: How Planes Fly: Revised Model (page 7)
- 2.4: How to Make an Airplane Fly (page 8)
- 2.5: Design Strengths and Failure points (page 9)
- 2.6: How Planes Fly: Final Model (page 10)

Required Preparation	Links/Additional Information
❑ Gather or purchase all necessary materials	Refer to the Materials List below
❑ Set up the stations for student investigations	Refer to the Materials List below and the Four Stations list above
❑ Review all videos and resources in the Suggested Teacher Resources	Refer to the Suggested Teacher Resources at the end of this lesson

Materials List

Item	Description/Additional Information	Quantity	Where to Locate/Buy
Standard 8.5” x 11” computer paper		5–10 pieces per student	Available in most schools
Standard 12” ruler		1 per student	Available in most schools
Straws	Provide each student with one straw to use during the stations activity	1 per student	Available at most stores
20 cm x13 cm computer paper	Cut computer paper to meet the size requirements	5 or 6 pieces	Available in most schools
Ping pong balls		5 or 6 balls	Available in most stores
Notebook paper		6–8 pieces	Available in most schools
Paper helicopters	Make the helicopters prior to student investigations	5 or 6 helicopters	[Web Link]

Day 2: How Planes Fly

Introduction (5 minutes)

Begin the lesson by leading a short class discussion on flight. Ask students to share what they already know about what makes things fly. At this point in the lesson, accept all responses.

Pose the question, *How can an airplane fly?* Generate interest in the question by emphasizing the weight and size of the airplane. Students might be perplexed about why a massive airplane can fly through the air.

Instruct students to develop an initial model that shows how airplanes are able to fly on 2.1: How Planes Fly: Initial Model on page 4 in the Spy Gliders Student Handbook.

Students should record their ideas in words, pictures, and diagrams. Students should attempt to articulate the forces involved in flight. Again, at this point in the lesson, accept all ideas.

NGSS Key Moment

Use students' draft models to gage their understanding of the forces involved in flight. Provide appropriate supports or extensions throughout the lesson according to student performance on this task.

Investigation: How Objects Fly (15 minutes)

After creating their initial models, students might have questions about how airplanes fly. Students engage in a series of investigations to better understand flight. Each investigation is designed to help students develop initial ideas about the forces involved in flight.

Introduce students to 2.2: Stations: How Objects Fly: Stations on pages 5 and 6 **in the** Spy Gliders Student Handbook**.** In this activity, students work in teams to complete four stations. At each station, students engage in an investigation designed to help them better understand the science of flight. The four stations, materials, and associated questions are listed below. Directions for folding the helicopters can be found at Paper Helicopters.

Video Link

▶ Paper Helicopters [Web Link]

Station #1: Tent with a Straw

Materials—Enough straws for each student, 5 or 6 pieces of 20 cm x 13 cm paper

1. Fold a 20 cm by 13 cm piece of paper in half to make a tent.
2. Place the paper tent on the desk.
3. Using a straw, blow under the tent and observe what happens.
4. Blow harder and observe what happens.
5. Try blowing hard against the side of the tent and observe what happens.

- What happened?
- How can you explain this?

Station #2: Ball and Straw

Materials—Enough straws for each student, 5 or 6 ping pong balls

1. Bend a flexible straw so the short end is pointing up.
2. Hold a ping pong ball over the opening of the straw and blow.
3. Let go of the ball and observe what happens.
4. What happens if you tilt the straw?

- What happened?
- How can you explain this?

Station #3: Paper Paper

Materials—6 to 8 pieces of notebook paper

1. Hold two pieces of notebook paper in front of you about 5 cm apart.
2. Blow hard between the papers and observe what happens.

- What happened?
- How can you explain this?

Station #4: Paper Helicopters

Materials—5 or 6 premade paper helicopters

1. Obtain a premade paper helicopter.
2. Drop the helicopter from a height and notice how it falls.
3. Change the shape/direction of the blades.
4. Does this change the direction or speed of the rotation?
5. What is making this rotate?

- What happened?
- How can you explain this?

As students rotate through the stations, monitor team work. Ask students probing questions to help them think about the forces involved in flight. Students should complete 2.2: How Objects Fly: Stations on pages 5 and 6 in the Spy Gliders Student Handbook.

After conducting the investigations, have students develop a revised model for how airplanes fly on 2.3: How Planes Fly: Revised Model on page 7 in the Spy Gliders Student Handbook. Students should incorporate evidence from their investigations in the revised model.

Design Work: Designing Prototype Paper Airplanes (10 minutes)

Now that students have developed initial ideas about flight, they test their ideas by designing prototype paper airplanes. Students work to determine the characteristics of airplaine design that help planes travel long distances. To do so, students develop model airplanes and test which characteristics impact distance traveled.

Students begin this process by brainstorming potential designs. Distribute paper and rulers to students. Instruct them to turn to 2.4: How to Make an Airplane Fly on page 8 in the Spy Gliders Student Handbook. Working individually, students sketch a paper airplane that they believe will travel the greatest distance, with a minimum expectation of at least 5 feet. Students should include labels and measurements in their sketches. They should also provide reasons as to why

certain design features might help their planes fly farther. Students should draw on the station investigations to justify their design decisions.

After students complete their designs, have them use the provided paper to carefully construct their paper airplanes based on their blueprints. They should also write down a prediction about how far or how well their planes will fly.

NGSS Key Moment

Use students' draft designs and justifications to gage their progress on MS-PS2-2. Provide appropriate supports or extensions throughout the lesson according to student performance on this task.

Extension

Consider providing students with a starting point for their airplane designs, such as providing students with a link to FoldnFly or distribute a printout of example airplanes.

Design Work: Testing Prototype Paper Airplanes (10 minutes)

Have students work with a partner to test their gliders. Encourage them to throw the plane consistently so they can observe how different designs affect flight. They should also sketch and note design strengths as well as failure points or weaknesses for at least two of the gliders on 2.5: Design Strengths and Failure Points on page 9 in the Spy Gliders Student Handbook.

After testing their airplane, have students develop a final model for how airplanes fly. Students should record their model on 2.6: How Planes Fly: Final Model on page 10 in the Spy Gliders Student Handbook. Emphasize that students should incorporate evidence from the stations activity and from the prototype paper airplane activity.

NGSS Key Moment

Have students record quantitative and qualitative data to measure how well the airplane flew. Students can measure distance traveled, stability, or direction traveled. Students should incorporate these observations in the "Failure Points" boxes in the student handbook.

Whole Group Discussion: How do planes fly? (10 minutes)

Engage students in a whole group discussion to try to come to consensus about how planes fly. Focus specifically on the forces involved in flight. The goal of the discussion should be to generate a class model for flight that shows the forces involved in flight.

Students may discuss the concepts of lift, thrust, gravity, and drag, although they may not necessarily use the appropriate vocabulary to discuss the concepts. Once students have developed the science ideas behind lift, thrust, gravity, and drag, introduce students to the appropriate vocabulary by showing them the picture below.

NGSS Key Moment

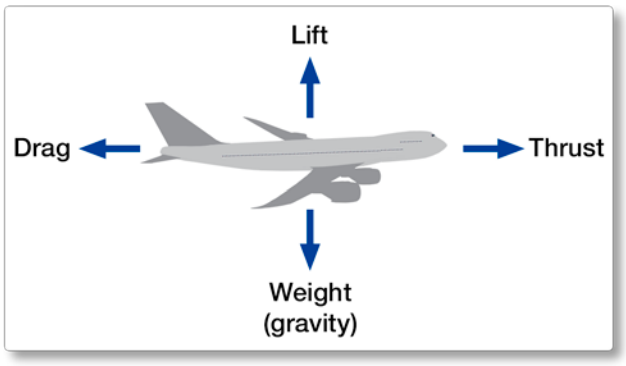
Whole group discussions, particularly consensus discussions, can be an effective way to engage students in the science practices of argumentation and explanation. Leading whole group discussions requires proper preparation. Refer to the Talk Science Primer for useful strategies.

For more information, access NASA: Four Forces on an Airplane, and as a class, review thrust, weight, lift, and drag.

To conclude the discussion, show the Aerodynamics of Flight, Science of Flight—Part 1, or PBS—Challenge of Flight video to students. For additional information on the forces of flight and paper airplanes, view BrainPop Flight Adventures, The Thrill of Flight, Fold N Fly, Fun Paper Airplanes, and Michael Despezio Inspired Planes.

Web Resources

- NASA: Four Forces on an Airplane [Web Link]



Video Links

- Aerodynamics of Flight [YouTube Link]
- Science of Flight—Part 1 [YouTube Link]
- PBS—Challenge of Flight [Web Link]
- BrainPop Flight Adventures [Web Link]
- The Thrill of Flight [Web Link]
- Fold N Fly [Web Link]
- Fun Paper Airplanes [Web Link]
- Michael Despezio Inspired Planes [Web Link]

Extension

To further support or extend student understanding of the forces involved in flight, consider purchasing small polystyrene gliders (commonly found in the party favor sections of stores) and long bamboo skewers (found in most grocery stores). Carefully insert the skewers horizontally, just under the wings to show the horizontal axis. Do the same through the fuselage at the center of gravity to form a vertical axis. For a horizontal axis from front to back (nose to tail), shorten two skewers and insert the pointed ends through the nose and tail. Make one plane for each team. Give students time to explore and visualize thrust, lift, gravity, and drag. Also consider introducing the following motions of flight: *pitch*, *roll*, and *yaw*.

Assessment

Several opportunities for formative assessment exist in this lesson:

- Spy Gliders Student Handbook entries can be used to monitor student progress throughout the module. For this lesson, pay particular attention to the series of models explaining how planes fly (2.1: How Planes Fly: Initial Model, 2.3: How Planes Fly: Revised Model, and 2.6: How Planes Fly: Final Model). Also consider using student design ideas (2.4: How to Make an Airplane Fly and 2.5: Design Strengths and Failure Points) to gage student progress in understanding and engaging in the engineering design process.
- Whole class share-outs and discussions allows for formative assessment of student ideas and building content knowledge.
- When students are meeting in their teams, spend time with each team, listening in on their process and providing support as needed.

Use the identified assessment opportunities to monitor student progress on disciplinary core ideas, science and engineering practices, and crosscutting concepts. Provide appropriate supports or extensions when necessary.

Reference Appendix B for suggestions for meeting the needs of all learners.

Community Connections

If any student's parents, guardians, family members, or relatives work as aerospace engineers, materials engineers, pilots, or aviation mechanics, consider inviting them to visit the classroom as volunteers or to share their work experiences.

Suggested Teacher Resources

Meeting the Needs of All Learners	Spy Gliders Teacher Handbook, Appendix B
Talk Science Primer	[Web Link]
The Aerodynamics of Flight video	[YouTube Link]
The Science of Flight—Part 1 video	[YouTube Link]
NASA Four Forces oon an Airplane	[Web Link]
PBS—Challenge of Flight	[Web Link]
Directions for Paper Helicopters	[Web Link]
BrainPop Flight Adventures	[Web Link]
The Thrill of Flight	[Web Link]
Fold N Fly	[Web Link]
Fun Paper Airplanes:	[Web Link]
Michael Despezio Inspired Planes	[Web Link]