Science and Innovation

A Boeing/Teaching Channel Partnership

SPY GLIDERS

Teacher Handbook

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Spy Gliders

Day 3: How Weight Affects Flight

Grade Level	Middle School
Lesson Length	One 50-minute session

Lesson Overview

In this lesson, students dig into their roles as engineers by working through the engineering design process to solve a challenge. This challenge involves modifying a polystyrene airplane to travel a certain distance while carrying a certain number of paper clips. Adding a payload to the glider, without affecting its ability to fly successfully, is a major component of the capstone engineering design challenge.

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: Planning and Carrying Out Investigations, Analyzing and Interpreting Data, Constructing Explanations and Designing Solutions
- 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 test what happens when they add weight to their gliders. Students experiment with ways to attach the weight to the glider to maximize the distance traveled. They collect data from their tests and make modifications to try to improve their gliders. At the end of the lesson, students engage in a discussion to try to explain how the weight impacted their gliders.

Dimension	NGSS Element	Connections to Classroom Activity
Science and Engineering Practices	**Planning and Carrying Out Investigations** • *Plan an investigation individually and collaboratively* and in the design identify independent and dependent variables and *controls, what tools are needed to do the gathering, and how many data are needed to support a claim.* **Analyzing and Interpreting Data** • *Analyze and interpret data to determine similarities and differences in findings.* **Constructing Explanations and Designing Solutions** • *Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process, or system.*	Students plan a strategy to systematically test their gliders after they add weight. Students carry out their systematic process. Students do not identify the variables outright, but they do identify the controls and the data to collect. After carrying out their tests, students use the data they collect to make changes to their gliders. When students share their results with the class, they compare and contrast findings. Students work with the ideas of forces and motion to design a glider capable of carrying a payload.
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 motion. For any given object, a larger force causes a larger change in motion.*	Students design a systematic process to test, modify, and retest their design solutions based on the results of the trials. Students consider combining characteristics of multiple solutions to create a solution that is better than its predecessors. Throughout the module, students conduct a variety of tests under different conditions. In the previous lesson, students tested glider designs. In this lesson, students test payload. In the final design, students incorporate aspects of all designs. In addition, students iteratively test their glider designs for carrying a payload. In this lesson, students experiment with adding mass to the glider. Students realize that when they add mass, more force is needed to help the glider travel the same distance. In addition, the placement of the mass makes a difference for glider performance.
Crosscutting Concepts	**Cause and Effect**	Through their investigations, students realize that when they move the mass, the glider flies differently.

	• Cause and effect relationships may be used to predict phenomena in natural or designed systems.	

Basic Teacher Preparation

Ensure that all of the supplies are laid out and students have access to the proper measuring equipment and materials.

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 3 are on pages 11 through 14 in the Spy Glider Student Handbook. The documents used in this lesson are:

- 3.1: How Weight Affects Flight (page 11)
- 3.2: How Weight Affects Flight: Payloads (page 12)
- 3.3: How Weight Affects Flight: Systematic Process (page 13)
- 3.4: How Weight Affects Flight: Work Space (page 14)

Required Preparation	Links/Additional Information
❑ Gather and set out all necessary materials	Refer to the Materials List below
❑ 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
Small action camera	An action camera is an engaging way for students to capture aerial footage during the final engineering design challenge. If it is cost prohibitive, a battery would be a suitable alternative.	1 per class	Camera [Web Link]
Foam (polystyrene) gliders	The longer the wing span, the better.	1 per team	Gliders [Web Link]
Metal washers		10 per team	Washers [Web Link]
Paper clips and washers	Paper clips can be used as fasteners or weights if you should use smaller gliders.	1 box per class	Any office supply store
Duct tape		1 roll per class	Any hardware store

Day 3: How Weight Affects Flight

Introduction (10 minutes)

Instruct students to sit in their prearranged teams, and have them read 3.1: How Weight Affects Flight on page 11 in the Spy Gliders Student Handbook. On this page, students are introduced to team roles. The team roles include: Project Director, Recorder, Material Manager, and Safety Direct. For teams of three, two roles can be combined. After reading about the roles, have students work together to choose a role for each member of the team. Students keep their roles for the remainder of this module.

Whole Group Discussion: Adding a Payload (5 minutes)

Tell students that the next part of their design problem is to make sure that their glider can carry a payload. Remind students of the purposes for their gliders. Their design task at this stage is to adapt a glider to travel a certain distance while carrying a certain number of washers. Point out all of the materials and demonstrate how to assemble the glider. Point out that the polystyrene glider is fragile.

Design Work: Team Planning (10 minutes)

Instruct students to review the design task on 3.2: How Weight Affects Flight: Payloads on page 12 in the Spy Gliders Student Handbook. Inform the class of the distance the gliders should fly and the number of washers that should be attached. Have students record the goal numbers. Then, have students work together in teams to sketch where and how to attach the washers to their gliders.

Helpful Tip

Determine the level of difficulty, and tell students the distance the glider should fly and the number of washers it should carry. If desired, consider having the class work together to determine these goals.

Students should defend their decisions by sketching force diagrams that include thrust, lift, gravity, and drag. Students should add the additional mass to the diagram and adjust their diagram as they see fit.

Investigation: Adding Weight (15 minutes)

Students work in their teams to complete 3.2: How Weight Affects Flight: Payload (page 12) and 3.3: How Weight Affects Flight: Systematic Process (page 13) in the Spy Gliders Student Handbook. Be sure they use the included guiding questions to help them determine which solution is the best option.

Students should then carry out their investigation plans. Students should use 3.4: How Weight Affects Flight: Work Space on page 14 in the Spy Gliders Student Handbook to record notes during testing.

NGSS Key Moment

Planning their own systematic testing process helps students make progress on Planning and Carrying out Investigations.

Whole Group Discussion: How Adding Weight Changes the Glider (10 minutes)

At the end of testing, have students reflect on the following prompt, *How did the sketch of the glider and the placement of the payload change over the course of testing?*

Engage students in a whole group discussion about how the glider changed. After students have started to observe some trends in how the glider changed, ask students why they think they needed to make the modifications to the glider. Guide students to the idea that when the mass changes, other forces involved must change so the glider can travel the same distance (as it might without the mass). At this point in the discussion, students should understand that mass makes a difference. Later, students model how mass impacts the forces involved in helping an airplane fly.

NGSS Key Moment

Thinking about how their gliders changed guides students to think about how adding mass caused the change.

Assessment

Several opportunities for formative assessment exist in this lesson:

- Spy Gliders Student Handbook entries can be used to monitor student progress during the module. For this lesson, focus specifically on 3.3: How Weight Affects Flight: Systematic Process on page 13 in the Spy Gliders Student Handbook to gage student progress on Planning and Carrying Out Investigations.
- 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, or other local professionals in these relevant fields, to visit the classroom as volunteers or to share their work experiences.

Suggested Teacher Resources

Meeting the Needs of All Learners	Spy Gliders Teacher Guide, Appendix B
Talk Science Primer	[Web Link]