Glider Flight and Early Innovators

Session Time: Three, 50-minute sessions

DESIRED RESULTS

ESSENTIAL UNDERSTANDINGS

Appreciate the rich, global history of aviation/aerospace and the historical factors that necessitated rapid industry development and expansion. (EU1)

Aspire to the highest level of technical proficiency as it relates to flight operations and engineering practices. (EU5)

ESSENTIAL QUESTIONS

1. How have gliders contributed to modern flight?
2. What makes a glider different from an airplane?
3. How do gliders stay aloft without an engine?

LEARNING GOALS

Students Will Know

- How early glider innovators contributed to modern flight
- How a glider flies
- How lift, weight, thrust, and drag create flight

Students Will Be Able To

- *Describe* how the methodical testing of gliders led to the evolution of modern aircraft (DOK-L2)
- *Explain* how the four forces of flight work together to keep an object aloft (DOK-L2)
- *Apply* engineering practices to a performance challenge (DOK-L4)

ASSESSMENT EVIDENCE

Warm-up
Ask students what they experience about the force of drag, the reduction of drag, and the force of lift in a demonstration involving cardboard and a fan.

Formative Assessment
Students write about how Bernoulli's Principle is demonstrated through an activity the students will have completed. They will also include a diagram.

Summative Assessment
Students write several paragraphs reflecting on how the four forces of flight work to keep gliders and other aircraft aloft.

LESSON PREPARATION

MATERIALS/RESOURCES

- Glider Flight and Early Innovations Presentation
- Glider Flight and Early Innovations Student Activity
- Glider Flight and Early Innovations Teacher Notes

Warm-Up Activity

- Large pieces of cardboard (about 20 x 30 inches)
- Fan

Paper Tent Activity

- 8 -inch x 11-inch pieces of paper for each student

Glider Building Activity

- Balsa wood gliders (one kit per student)
- Extra balsa wood
- Craft knives, one per student pair
- Stopwatch or other timing device (or use cell phone app)
- Tape measure
- Masking or electrical tape
- Glue
- Other simple materials for modifying glider designs (index cards, paper, tape, sticky notes, paper clips, putty, etc.)

SAFETY

Review safety rules when in a lab situation; pay close attention to the use of fans so students do not stick anything between fan blades while the blades are moving.

LESSON SUMMARY

Lesson 1: From Birds to Gliders
Lesson 2: Glider Flight and Early Innovations

This lesson consists of three sessions. In the first session, students will discuss what they experience about the force of drag, the reduction of drag, and the force of lift in a demonstration involving cardboard and a fan.

A class discussion will guide the students through a lecture on important glider pioneers, George Cayley and Otto Lilienthal, and their contributions to solving the problem of manned flight.

In the previous lesson, students were introduced to the four forces of flight. A class discussion and video with further explore the concepts involved in keeping a glider in the air. Students will also experience a demonstration of Bernoulli's Principle during a short hands-on activity.

During the second and third sessions of this lesson, students will experiment with lift by building and testing gliders. During this activity, students will utilize engineering practices they learned in unit one. Each student will build and fly their own glider. They will select one or more of the flying challenges suggested in the activity and then work to achieve the best possible performance of their glider through testing, modifying, and re-testing their gliders. Students will communicate their findings to the class.

As a summative assessment, students will write several paragraphs reflecting on how the four forces of flight work to keep gliders and other aircraft aloft.

BACKGROUND

It is important for students to understand what a glider is and more about early glider innovators. These innovators' contributions had tremendous influence toward developing powered and controlled flight. Orville and Wilbur Wright used knowledge gained from gliders.

For a long time, people attempted flight by designing machines or outfits that would allow them to fly by flapping like a bird (refer back to **Da Vinci and His Flying Machines**). Eventually those early innovators learned that a human could never generate enough power to get a machine that flapped like a bird into the air. The first aircraft designers to succeed at building airplanes learned how to build aircraft that could glide before they tried to build aircraft that could fly.

Early successful pioneers of heavier-than-air manned flight abandoned the idea of flapping like a bird and instead focused on gliding, using fixed systems whose energy came not from flapping wings but rather from height or a launch system similar to a squirrel jumping from a tree. George Cayley is regarded as one of the first true pioneers of aeronautical science, establishing the ideas of the forces of flight, the effectiveness of a cambered wing, and separate systems for propulsion, lift, and control. With Caley's understanding of the mechanics of flight, he developed the first recorded heavier-than-air glider. As he continued his testing of his systems, he shared his findings. Wing dihedral (wings lower in the middle than at the tips) contributes greatly to aircraft stability, and it is one of George Cayley's many discoveries that we can still see in use in modern aircraft today.

Almost a century after George Cayley, the Wright brothers, learning from much of his work, began working on their own glider. The Wright brothers used their glider as a test bed to perfect lift and control techniques before eventually developing it into the first powered, controlled, manned heavier-than-air flight. The first and second gliders that the Wrights created both performed very poorly, and as a result the Wrights continued to research hundred of wing designs with the use of a wind tunnel. The third glider model the Wrights developed flew well--so well, in fact, that they flew it hundreds of times. The reason they conducted so many flights was to continue to perfect the lift and control surfaces. In the nearly hundred years between George Cayley's first ideas and the Wright brothers' first flight, there were numerous other pioneers that continued to build, test, and fly gliders. Each iteration of their glider was an improvement on the last and tested a new idea and concept that continued to drive aviation innovation.

MISCONCEPTIONS

Even though gliders don't have an engine, they still produce thrust.

DIFFERENTIATION

To promote reflective thinking and guided inquiry in the second part of the activity in the **EXTEND** section of the lesson plan, circulate around the classroom and assist students who might have trouble coming up with ideas for modifying their gliders. Ask questions that provoke their own ideas for possible answers.

LEARNING PLAN

ENGAGE

Teacher Material: [Glider Flight and Early Innovators Presentation]

Slides 1-3: Introduce the topic and learning objectives for this lesson.

Slide 4: Conduct the **Warm-Up.**

Warm-Up

In groups of 3 to 4 students, students will create an illustration that explains the concepts of lift, thrust, drag, and weight in flight. They might want to consider explaining these concepts in relation to differences between gliders and airplanes, or animals that glide and animals that fly. Invite students to brainstorm ideas first.

Possible answers:
Drag acts to slow the speed of an object through the air. The shape of the object determines the amount of drag which is produced. Objects that are streamlined produce the least amount of drag.

Lift enables an object to climb into the air and remain aloft during flight. If an object is held flat against a stream of air, it is pushed backward. However, if the edge of the object is rotated forward toward the ground, the air can now push it up as well as back.

Take no more than 5 minutes to complete this Warm-Up.

[DOK-L2; *Cause and Effect*]

EXPLORE

Teacher Material: Glider Flight and Early Innovators Presentation

Slide 5:

1. The teacher will hold up a large piece of cardboard in front of a fan so that the wind blows against the flat side. What do you think will be felt?
The teacher will feel thrust from the fan pushing horizontally against the cardboard. Also, the teacher may feel like the cardboard is sinking down due to weight, depending on the speed of the fan.

2. The teacher will turn the cardboard sideways with the edge facing the wind. What happens?
The teacher may feel like the cardboard is very light and possibly may slip off of their hands.

3. The teacher will tilt the edge of the cardboard down slightly. What will happen?
The teacher may feel like the cardboard is getting slightly pushed horizontally, but not as much as when the cardboard was vertical. The cardboard may also feel like it is getting pushed down.

EXPLAIN

Teacher Material: Glider Flight and Early Innovators Presentation

Lead a class discussion on important glider pioneers and their contributions to solving the problem of manned flight.

Slides 6-7: Explain to students that a glider is a special kind of aircraft that has no engine.

Paper airplanes are the simplest gliders to build and fly. Balsa wood (which the students will experiment with in this lesson) or styrofoam toy gliders are an inexpensive toys. Hang-gliders are piloted aircraft having cloth wings and minimal structure. Some hang-gliders look like piloted kites, while others resemble maneuverable parachutes. Sailplanes are piloted gliders that have standard aircraft parts, construction, and flight control systems, but no engine.

Slides 8-14: Lead a class discussion on important glider pioneers and their contributions to solving the problem of manned flight. Impress upon students that early glider innovators identified the four forces of flight. Many of their discoveries are still being used in aircraft design and manufacturing today.

As part of the discussion, show a unique animation made from original photographs of Otto Lilienthal's glider flights.

- Otto Lilienthal's First Film (Length 2:03)
  http://video.link/w/eLKd

In an article students read in the last lesson, they were introduced to the concept that lift is created over a bird's wings when air over the top of the wings moves faster than air moving under them. This creates a pressure difference. Lower pressure is on top of the wing where the air is moving faster. The higher pressure under the wing (where the air is moving slower) lifts the bird upward. The shape of the bird's wings ensures that the air that passes over the top of the wings has a longer distance to travel than the air passing underneath the wings. This makes the air speed up as it passes over the top of the wing. The faster moving air over the wings ensures that the pressure above the wings is lower than the pressure underneath the wings. The higher air pressure beneath the wings creates lift.

Slide 15: Show a video to explore lift as defined by Bernoulli's Principle. The video also explains all four forces of flight.

- "How Do Planes Fly?" (Length 4:29)
  http://video.link/w/LJJd

Slide 16-17: Conduct the Paper Tent activity as a demonstration of Bernoulli's Principle.

Eighteenth-century Swiss mathematician Daniel Bernoulli discovered that when a fluid (such as moving air) changes speed, its pressure also changes. Airplane wings are specially designed to take advantage of this. Wings are designed so the air moving over the top of the wing is forced to speed up more than the air moving below the wing. The air speeds up because an airplane's wing is an obstacle to the oncoming air. As the air meets the wing, its path narrows. But the amount of air moving past remains the same. Think of water moving past rocks in a creek. The rocks are an obstacle that narrows the path of the flowing water. But the amount of water that must pass by remains the same. The flowing water speeds up as its path narrows around the rocks.

Paper Tent Activity (demonstration of Bernoulli's Principle)

1. Have students fold a piece of paper in half and make paper tents. The fold can be lengthwise or widthwise. Have them place their tents on a flat surface so they form an inverted V.

2. Have students predict what will happen when they blow through the tents. Likely answers might be that the tents will fly up or blow away.

3. When the students blow into the tents, they will flatten.

Ask students why the tents flatten. This happens because the air moving through the inverted "V" is faster, so it has less pressure. With less pressure inside the tent and higher pressure outside, the piece of paper flatten.

Slides 18-20: Explain to students the concept that even though a glider doesn't have an engine, it must generate thrust to fly. It does this by converting potential energy, in the form of altitude, into kinetic energy.

Reinforce how lift is created over the wing of a glider.

Slide 21: Conduct the **Formative Assessment**.

Formative Assessment

Ask students to write a paragraph or two about how the Paper Tent Activity relates to Bernoulli's Principle. They should include a diagram with their paragraph.

Student answers will vary. The air moving through the inverted V is moving faster than air around it, so has less pressure. With less pressure inside the tent, and higher pressure outside the tent, the piece of paper flattens. This is exactly what Bernoulli's Principle says occurs in fluid and in this case, "air" is the fluid.

Allow up to 10 minutes for the formative assessment and collect student work. Grade up to 10 points based on completeness and participation.

[DOK-L2; summarize, cause and effect, DOK-L3; explain phenomena in terms of concepts]

EXTEND

Teacher Materials: Glider Flight and Early Innovators Presentation, Glider Flight and Early Innovations Teacher Notes
Student Material: Glider Flight and Early Innovations Student Activity

Slide 22: This section will begin in session two and continue into session three. Use the **Glider Flight and Early Innovations Student Activity** where students will experiment with lift by building and testing gliders. During this activity, students will utilize engineering practices they learned in unit one. These practices stress that scientific inquiry is a balance of skills and knowledge.

Each student will build and fly their own glider. They will select one or more of the flying challenges suggested in the activity and then work to achieve the best possible performance of their glider through testing, modifying, and re-testing their gliders.

In part one of the activity, students will set-up the investigation and determine how they will complete the activity. They will identify criteria and constraints, brainstorm ideas on how to achieve maximum performance, and decide how they will collect and measure data from each trial.

In part two, students will build their gliders using only the pieces provided in the balsa wood glider kits and perform the "control" tests. They will analyze their results and determine how to modify their gliders using additional materials provided by teachers.

In part three, students will make modifications to their gliders and retest them several times, attempting to improve the performance. This is the "experimental" test.

In part four, students will compare data, analyze their results, and communicate their findings to the class.

As students work through this activity, they will use the engineering practices introduced in the first unit. Remind students these practices are not necessarily all used to solve a problem, or used in any particular order.

1. Asking questions and defining problems

2. Developing and using models

3. Planning and carrying out investigations

4. Analyzing and interpreting data

5. Using mathematics and computational thinking

6. Constructing explanations and designing solutions

7. Engaging in argument from evidence

8. Obtaining, evaluating, and communicating information

EVALUATE

Student Material: Glider Flight and Early Innovators Presentation

Slide 23: Conduct the **Summative Assessment.**

Summative Assessment

Ten minutes before the end of class, have students individually write 2-3 paragraphs reflecting on how the four forces of flight work to keep gliders and other aircraft aloft. They should draw from what they learned during the student activity to explain their reasoning.

[DOK-L3; *draw conclusions*, DOK-L2; *relate*]

Summative Assessment Scoring Rubric

Follows assignment instructions

Postings show evidence of one or more of the following:

- Knowledge of the four forces of flight
- Knowledge of how aircraft design influences flight

Writing shows an understanding of the concepts covered in the lesson

Writing shows in-depth thinking including analysis or synthesis of lesson objectives

Points	Performance Levels
9-10	Consistently demonstrates criteria
7-8	Usually demonstrates criteria
5-6	Sometimes demonstrates criteria
0-4	Rarely or never demonstrates criteria

GOING FURTHER

Have students research how modern gliders are launched. If a local airport offers gliding lessons or has a gliding club, have students interview glider pilots to learn more.

STANDARDS ALIGNMENT

NGSS STANDARDS

Three-dimensional Learning

- **HS-PS2-3** - Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.
    - Science and Engineering Practices
        - Constructing Explanations and Designing Solutions
    - Disciplinary Core Ideas
        - PS2.A: Forces and Motion
        - ETS1.A: Defining and Delimiting an Engineering Problem
        - ETS1.C: Optimizing the Design Solution
    - Crosscutting Concepts
        - Cause and Effect
- **HS-ETS1-1** - Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
    - Science and Engineering Practices
        - Asking Questions and Defining Problems
        - Constructing Explanations and Designing Solutions
    - Disciplinary Core Ideas
        - ETS1.A: Defining and Delimiting Engineering Problems
    - Crosscutting Concepts
        - Systems and System Models
        - Influence of Science, Engineering, and Technology on Society and the Natural World
- **HS-ETS1-2** - Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
    - Science and Engineering Practices
        - Constructing Explanations and Designing Solutions
    - Disciplinary Core Ideas
        - ETS1.C: Optimizing the Design Solution
    - Crosscutting Concepts
        - none
- **HS-ETS1-3** - Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.
    - Science and Engineering Practices
        - Constructing Explanations and Designing Solutions

- Disciplinary Core Ideas
    - ETS1.B: Developing Possible Solutions
- Crosscutting Concepts
    - Influence of Science, Engineering, and Technology on Society and the Natural World

COMMON CORE STATE STANDARDS

- **RST.9-10.1** - Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
- **RST.9-10.2** - Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.
- **RST.9-10.4** - Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
- **RST.9-10.5** - Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy).
- **RST.9-10.7** - Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
- **RST.9-10.8** - Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem
- **WHST.9-10.1** - Write arguments focused on discipline-specific content.
- **WHST.9-10.2** - Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.
- **WHST.9-10.4** - Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
- **WHST.9-10.6** - Use technology, including the Internet, to produce, publish, and update individual or shared writing products, taking advantage of technology's capacity to link to other information and to display information flexibly and dynamically.
- **WHST.9-10.7** - Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
- **WHST.9-10.8** - Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.
- **WHST.9-10.9** - Draw evidence from informational texts to support analysis, reflection, and research.

REFERENCES

http://www.ctie.monash.edu.au/hargrave/cayley.html

https://airandspace.si.edu/collection-objects/lilienthal-glider

http://www.flyingmachines.org/lilthl.html

https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/phak/media/08_phak_ch6.pdf

https://www.grc.nasa.gov/www/k-12/airplane/glider.html