UNIT 2.D | Day 3-7 | LESSON PLAN

BUILD AND TEST A WIND TUNNEL

HIGH SCHOOLS POWERED BY AOPA

UNIT 2: TAKING FLIGHT — Early Aviation Innovations

SECTION D Powered, Controlled Flight

TIME OF LESSON Five, 50 minute periods

DESIRED RESULTS

ESSENTIAL UNDERSTANDINGS

Historically, aviation and aerospace technology have evolved as concerns about efficiency and safety have been addressed. (EU1)

Innovators in the world of aviation use engineering design and the scientific process to advance aviation technology and procedures, and improve aviation safety. (EU2)

ESSENTIAL QUESTIONS

1. Should the Wright Brothers be viewed as leaders in aviation or contributors?

Students Will Know

- How the Wright Brothers improved their designs through the use of a wind tunnel
- Which airfoils create more lift by looking at their shape and characteristics

Students Will Be Able To

- *Describe* the scientific process the Wright Brothers used to solve the power, control, and lift problems they encountered. (DOK-L2)
- *Analyze* the historical significance of the Wright Brothers and others who made contributions to early powered flight. (DOK-L4)

ASSESSMENT EVIDENCE

Pre-Assessment Watch the video and ask informal driving questions.

Formative Assessment Ask students open-ended questions throughout the build of the wind tunnel and airfoils to gauge student understanding.

Post-Assessment Use a 3-2-1 exercise to help students reflect on what they've learned.

INSTRUCTION AND FORMATIVE ASSESSMENT PLAN

Materials/Resources Needed

Lesson Resources

- 2.D.Day 3-7 STUDENT NOTES 1
- 2.D.Day 3-7 POWERPOINT 1
- 2.D.Day 3-7 TEACHER AID 1
- 2.D.Day 3-7 STUDENT ACTIVITY 1

Wind Tunnel Build (per wind tunnel)

- Large pieces of cardboard cut into the following dimensions
  - Four (4) 21" x 25" x 8"
  - Four (4) 40" x 8"
- Box fan (highest powered fan available)
- Box knife
- Metal straight edge
- Measuring tape/ruler
- Drinking straws (recommend using jumbo size straws)
- One (1) 8" x 10" piece Lexan/Plexiglass (can be purchased pre-cut at a major hardware store)
- Duct tape
- Hot glue gun and glue sticks
- Digital scale (measures to 0.1g, at a minimum)
- Safety glasses

Airfoil Build (per small group)

- Airfoil Mount (assume each group builds one airfoil mount to test both airfoils)
  - Foam board pieces (recommend using standard white foam board from Dollar Tree)
    - One (1) 6" x 6"
    - Eight (8) 1" x 3"
  - Wire (can be from a wire hanger)
    - Three (3) 7 ½" pieces of wire
- Symmetrical Airfoil
  - Foam board pieces
    - One (1) 16" x 5 ¼"
    - Three (3) 5 ¼" x 1"
- Asymmetrical Airfoil
  - Foam board pieces
    - One (1) 16" x 5 ¼"
    - Three (3) 5 ¼" x 1"
- Box knife
- Metal straight edge
- Measuring tape/ruler
- Hot glue gun and glue sticks
- Pliers/wire cutter
- Protractor
- Safety glasses

Safety

- Actively supervise students during the activity. Be ready to offer guidance in situations where safety could be compromised.
- Make sure students use eye protection. Have available insulated gloves for handling hot objects and pads for setting down objects with heated surfaces.
- Explain how to safely store sharp objects on an active workspace when they are not in use. Students should not be holding sharp objects or tools when they are not in use.
- Sharp tools should be stored in their protective cases when not in use.

Lesson Summary

This lesson is day three through seven of Unit 2, Section D. Section D comprises eight days.

Day 1- 2: The "Wright" Approach
Day 3 - 7: Build and Test a Wind Tunnel
Day 8: The "Wright" Attitude

Throughout the multi-day lesson, students will build a wind tunnel as a class and then build airfoils to test in the wind tunnel. The class will start with a video about a very precise wind tunnel used today. The students will then explore the reasons why the Wright Brothers built a wind tunnel and the process they used to test airfoils.

Students will then build a wind tunnel, learn about airfoils, build their own airfoils, and test their airfoils. It will take about two lessons to build the wind tunnel, an additional two lessons to build their airfoils and the airfoil mount, and one final day to test the airfoils, summarize their findings, and present them to the class. Students will build and test airfoils in small groups.

The teacher will use a use a 3-2-1 exercise to help students reflect on what they've learned.

Background

The students have been learning about the Wright Brothers and their decision to measure the lift and drag on their various airfoils using a simple wind tunnel. They built airfoils, tested them, identified areas for improvement and then re-tested the designs. They were the first to use this process to systematically test their theories and design their gliders and airplanes.

Learning Activity	Assessment
Engage Show the video "Boeing 737 MAX Winglets in the Wind." (Length 2:08) The students will get an understanding of the precision and scale of today's wind tunnels. https://www.youtube.com/watch?v=vD828p9Nt0U Ask students the following questions and lead a class discussion: *Why are wind tunnels used to design aircraft? What do they measure? A wind tunnel provides a means to test aircraft and their components in order to determine their performance and behavior in the air. Wind tunnels provide a way to test objects in a much more cost effective and safe manner. Wind tunnels allow for the measurement of aerodynamic forces and airflow around an object. The objects tested can be entire aircraft models, airfoils, engines, rockets, and more.* *What other industries besides aviation use wind tunnels to test designs? The automobile, boating, and motorsports industries all use wind tunnels. The sporting goods industry uses them to test things like helmets and golf balls*	**Pre-Assessment** Watch the video and ask informal driving questions.

Explore

In the early 1900s, the Wright Brothers realized that their gliders were only producing a fraction of the lift predicted by Otto Lilienthal's previous experiments. In order to improve on their designs, they built a wind tunnel and developed the first version of the engineering design process.

Give students access to the following NASA webpage and have them complete the graphic organizer **(3.D.Day 3-7 STUDENT NOTES 1)** to help them learn more about the Wright Brothers' 1901 wind tunnel. https://wright.nasa.gov/airplane/tunnel.html

Explain/Extend

Over the next several lessons, students will build a wind tunnel, learn about airfoils, build their own airfoils, and test their airfoils. It will take about two lessons to build the wind tunnel, an additional two lessons to build their airfoils and the airfoil mount, and one final day to test their airfoils, summarize their findings and present them to the class. They will build and test airfoils in small groups.

Depending on the size of the class and supplies available, the teacher may opt to build multiple wind tunnels.

Refer to **3.D.Day 3-7 TEACHER AID 1** for detailed instructions on building the wind tunnel.

After the wind tunnel is built, lead a class discussion on airfoils. The presentation covers important terminology and factors that influence the performance of an airfoil. Refer to **3.D.Day 3-7 POWERPOINT 1.** During the presentation, have students take notes at the top of worksheet **3.D.Day 3-7 STUDENT ACTIVITY 1.**

In small groups, the students will build airfoils out of foam board. They will build a symmetrical airfoil of a given chord and span, and an asymmetrical airfoil of the same chord and span. They will test the airfoils at various angles of attack to determine which creates more lift.

To measure the lift of the airfoils, students will note the weight the airfoil assembly exerts on a digital scale before the wind tunnel is turned on and while the wind tunnel is running.

Take the following steps to measure lift:

1. Place the digital scale inside the wind tunnel
2. Ensure the digital scale has been "zeroed" out
3. Place the airfoil mount and the symmetrical airfoil on the scale
4. Looking through the viewing window, take note of the weight in grams (to the tenth or hundredth) before the wind tunnel is turned on

5. Turn on the wind tunnel (ensure the fan is at the highest powersetting)
6. After a few moments, take note of the new weight in grams (to the tenth of hundredth)
7. Subtract the weight found in step 6 from the weight found in step 4 to determine the amount of lift generated
8. Repeat these steps for both airfoils and the different angles of attack

Students will be asked to answer the following questions based on their results:

Which airfoil produced the most lift? Explain why.
If done correctly, the asymmetrical airfoil will create more lift. The Wright Brothers proved through the wind tunnel tests that cambered airfoils produced greater lift.

Which airfoil produced the most lift for a given angle of attack? Why?
If done correctly, the most lift will be created by the asymmetrical airfoil at 30 degrees angle of attack. This will be easier to determine if students are using a higher quality digital scale that measures to the hundredth of a gram.

Go back to your wind tunnel with your asymmetric airfoil. Mount the airfoil upside down so that the cambered side of the airfoil is facing the scale. Place the entire airfoil mount on the scale with the leading edge pointed toward the fan. Note the weight again before turning on the fan. What happens to the weight once the wind tunnel is turned on? Why?
The air doesn't know the airfoil is upside down, and the air moves around the airfoil just as it did before. The air on the cambered side of the airfoil is still lower pressure air than on the flat side. Just as before, this creates a force, but now that force is downward and places more pressure on the scale. The scale should indicate a weight greater than the no-wind weight.

What would you expect if we did the same exercise with the symmetrical airfoil?
A symmetrical airfoil will create the exact same amount of lift whether right side up or inverted. This is why aerobatic airplanes generally use symmetrical airfoils.

The students will then summarize the results and present their findings to the class.

If the teacher desires and time allows, the students can use the engineering design process to design and test their own airfoil.

Formative Assessment

Ask students open-ended questions throughout the build of the wind tunnel and airfoils to gauge student understanding.

Evaluate

Use a 3-2-1 exercise to help students reflect on what they've learned. Ask the students to answer the following questions in their interactive notebooks.

- List 3 things you learned about the use of wind tunnels.
- List 2 things you don't understand about the Wright Brothers and the process they used to test airfoils.
- List 1 thing you want to know more about in the engineering design process.

Post-Assessment

Use a 3-2-1 exercise to help students reflect on what they've learned.

Differentiation

Teachers may want to assign peer mentors to work with others students throughout the detailed build processes for the wind tunnel and the airfoils.

Going Further

If time allows, have students use the engineering design process to design and test their own airfoils. They could also set the airfoils to negative angles of attack and measure the decreases in lift.

STANDARDS ALIGNMENT

NGSS STANDARDS

Three-dimensional Learning

- **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 -** ADesign 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
- **HS-PS2-2 -** Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. (NOTE: This standard is not explicitly used as math is not required to complete the exercise).
  - Science and Engineering Practices
    - Using Mathematics and Computational Thinking
  - Disciplinary Core Ideas
    - PS2.A: Forces and Motion
    - PS2.B: Types of Interactions
  - Crosscutting Concepts
    - Systems and System Models
- **HS-ETS1-4 -** Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.
  - Science and Engineering Practices
    - Using Mathematics and Computational Thinking
  - Disciplinary Core Ideas
    - ETS1.B: Developing Possible Solutions
  - Crosscutting Concepts
    - Systems and System Models

COMMON CORE STANDARDS

- **HSN-Q.A.2-3 -** Reason quantitatively and use units to solve problems.
- **HSS-ID.B.5 -** Summarize, represent, and interpret data on two categorical and quantitative variables.
- **HSN-Q.A.2-3 -** Reason quantitatively and use units to solve problems.
- **HSS-ID.B.5 -** Summarize, represent, and interpret data on two categorical and quantitative variables.
- **RL.9-10.2 -** Determine a theme or central idea of a text and analyze in detail its development over the course of the text, including how it emerges and is shaped and refined by specific details; provide an objective summary of the text.
- **RL.9-10.4 -** Determine the meaning of words and phrases as they are used in the text, including figurative and connotative meanings; analyze the cumulative impact of specific word choices on meaning and tone (e.g., how the language evokes a sense of time and place; how it sets a formal or informal tone).
- **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 -** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9-10 texts and topics.

- **SL.9-10.1.C -** Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions.
- **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.9-10.8 -** 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.
- **HSN-Q.A.3 -** Choose a level

REFERENCES

https://www.fi.edu/history-resources/wind-tunnel

https://wright.nasa.gov/airplane/tunnel.html

http://www.dynamicflight.com/aerodynamics/airfoils/

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