Reducing Aviation's Environmental Impact

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 processes. (EU5)

ESSENTIAL QUESTIONS

1. How does aviation contribute to climate change?
2. How can we make aviation more environmentally friendly?

LEARNING GOALS

Students Will Know

- Two major categories of aviation's impact on the environment: emissions and noise
- Developments in aviation technology that have the potential to reduce aviation's impact on the environment

Students Will Be Able To

- *Recognize* the connection between advancements in technology and their potential to positively impact the environment. (DOK-L1)
- *Describe* aviation's impact on the environment. (DOK-L2)
- *Identify and summarize* several major developments in aviation that will reduce aviation's impact on the environment. (DOK-L2)

ASSESSMENT EVIDENCE

Warm-up
Students will read a short editorial and discuss how aviation contributes to climate change and who is responsible for reducing aviation's impact on the environment.

Formative Assessment
Students will select an emerging technology aimed at reducing aviation's environmental record and complete research.

Summative Assessment
Placing themselves in the position of an airline executive who has both budget priorities and corporate social responsibilities, students must select and write about one emissions- or noise-reducing technology they think holds the most promise for reducing aviation's environmental impact while being affordable to purchase and/or implement.

LESSON PREPARATION

MATERIALS/RESOURCES

- Reducing Aviation's Environmental Impact Presentation
- Reducing Aviation's Environmental Impact Student Activity 1
- Reducing Aviation's Environmental Impact Student Activity 2
- Reducing Aviation's Environmental Impact Student Notes

Building Chevrons Activity

- Thunder drum (small or large ones will work for this activity)
    - One needed or, if possible, several small ones to help with productivity
- Paper, cardstock, various building materials (i.e., aluminum foil)
- Measuring devices – decibel meter (real or smartphone app)
    - There are many free decibel meter apps. Simple app searches for "decibel meter" will show popular apps that include "Sound Meter," "Decibel Meter" and "SPL Meter."

LESSON SUMMARY

Lesson 1 - Reducing Aviation's Environmental Impact

To begin this three-session lesson, students will read a short editorial and discuss how aviation contributes to climate change and who is responsible for improving aviation's impact on the environment.

Students will learn how aviation's environmental impact falls into two general categories (emissions and noise) and will participate in a discussion about aviation's effect on the environment and on society in general.

During a hands-on activity, students will use engineering practices to create and evaluate a chevron design to dampen noise (simulating chevrons used on engine nozzles to reduce aircraft noise pollution). With a thunder drum to create sound waves, students will use cardstock and develop a chevron shape to wrap around the drum in an attempt to dampen sound coming from the drum. A decibel meter will be used to quantitatively evaluate the change in sound coming from the drum.

During a formative assessment, students will explore attempts to reduce emissions and noise in more detail by researching new technologies that are designed to improve aviation's environmental record.

Finally, students will place themselves in the position of an airline executive who has both budget priorities and corporate social responsibilities. They must select and write about one emissions- or noise-reducing technology they think holds the most promise for reducing aviation's environmental impact while being affordable to purchase and/or implement.

BACKGROUND

Broadly speaking, aviation's environmental impact falls into two general categories: emissions and noise. As the fastest-growing form of transportation, aviation's impact on the environment will continue to grow. Currently, aviation is responsible for about 2 percent of the world's human-induced carbon-dioxide emissions, but that percentage is expected to grow as aviation meets the needs of a growing world economy and expanding world population.

Innovation and problem-solving will reduce aviation's environmental impact in the future. According to Boeing, airliners today are 70 percent more fuel efficient and 90 percent quieter than the first jet aircraft. Technologies in development that will continue these improvements include biofuel research, wing-warping (which allows wings to actually change

shape and increase flight performance), lighter materials, more fuel-efficient engine designs, and quieter engine designs. In addition, more efficient flight paths tailored to specific needs and capabilities of each aircraft will shorten flights while maintaining safety. Shorter flight paths mean less fuel consumption, leading to less environmental impact.

MISCONCEPTIONS

Students may not immediately make the connection between aviation technological advancements and the potentially positive impacts they can have on the environment.

Many students have the mistaken impression that there is one distinctive approach common to solving engineering problems. In reality, practicing engineers employ a broad spectrum of methods.

DIFFERENTIATION

The chevron activity fosters differentiation by design. Students have many options when designing chevrons, providing choice and flexibility. More advanced students also can calculate differences in original sound-wave output by the thunder drum compared with the output with chevrons attached, using percentages, ratios, etc.

LEARNING PLAN

ENGAGE

Teacher Material: Reducing Aviation's Environmental Impact Presentation
Student Material: Reducing Aviation's Environmental Impact Student Notes

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

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

Warm-Up

Ask students to read the editorial provided in **Reducing Aviation's Environmental Impact Student Notes** and be prepared to discuss the following questions as a class.

- How does aviation contribute to climate change?
- Who is responsible for reducing aviation's impact on the environment?

Allow volunteers to share their answers, and allow for a brief discussion.

[DOK 3; *formulate, hypothesize*]

Questions

How does aviation contribute to climate change?

Airplanes emit heat, noise, particulates, and gases that contribute to climate change. The rapid growth in air travel contributes to an increase in total pollution attributable to aviation.

Who is responsible for reducing aviation's impact on the environment?

Students may posture that both individuals and companies are responsible for reducing aviation's impact on the environment. According to the editorial, individuals can fly less. Passengers also may

consider flying airlines that are the most environmentally conscious. In addition, manufacturers and the industry have a responsibility in reducing emissions and noise pollution. Manufacturers must work to make their airplanes as fuel efficient as possible, using lightweight materials and biofuels.

EXPLORE

Teacher Material: Reducing Aviation's Environmental Impact Presentation

Slide 5: Tell students that the number of commercial aircraft flying across the world will double by 2037. Aviation's environmental impact will continue to grow unless steps are taken to reduce it.

Slide 6: Broadly speaking, aviation's environmental impact falls into two general categories: emissions and noise. Aircraft engines produce emissions that are similar to other emissions resulting from fossil-fuel combustion. However, aircraft emissions are unusual in that a significant proportion is emitted at altitude. These emissions give rise to important environmental concerns regarding their global impact and their effect on local air quality at ground level.

Noise emissions are created by an aircraft's engines, propellers, or components on the ground, during takeoff on departures, flying overhead while en route, or during landing.

Slide 7: Like all human activities involving combustion, aircraft emit particles and gases such as carbon dioxide (CO2), water vapor, hydrocarbons, carbon monoxide, nitrogen oxides, sulfur oxides, lead, and other pollutants that interact among themselves and with the atmosphere.

Slide 8: Aircraft emissions that occur below 3,000 feet generally are considered air-quality pollutants. The Environmental Protection Agency has a tool to find the Air Quality Index for a certain region in the country: https://www.epa.gov/outdoor-air-quality-data/air-quality-index-report. Aircraft emissions contribute to these AQI measurements.

Aircraft emissions that occur above 3,000 feet generally are considered greenhouse gases. A greenhouse gas contributes to the greenhouse effect by absorbing infrared radiation, e.g., carbon dioxide.

Slide 9: CO2 emissions are the most significant and best understood element of aviation's total contribution to climate change. The level and effects of CO2 emissions currently are believed to be broadly the same regardless of altitude. Aviation is responsible for about 2 percent of the world's human-induced carbon-dioxide emissions, but that percentage is expected to grow as aviation meets the needs of a growing world economy and expanding world population.

Slide 10: One of the products of burning hydrocarbons with oxygen is water vapor, also a greenhouse gas. Water vapor produced by aircraft engines at high altitude, under certain atmospheric conditions, condenses into droplets to form condensation trails, or contrails. Contrails are visible lines of clouds that form in cold, humid atmospheres and are thought to have a global warming effect (though one less significant than CO2 emissions.

Slide 11: In addition to the CO2 released by aircraft in flight through the burning of fuels, the aviation industry contributes greenhouse-gas emissions from ground airport vehicles and those used by passengers and staff to access airports, as well as through emissions generated by the production of energy used in airport buildings, the manufacture of aircraft, and the construction of airport infrastructure.

Slide 12: Ask students what they think is the most effective way to reduce aircraft emissions.

Questions

What is the best way to reduce aircraft emissions?

Students may say that anything that reduces fuel consumption will reduce emissions. This can be accomplished by the types of technology that are incorporated on aircraft, such as mechanisms to reduce drag. They also may point out that anything that reduces air traffic delays or shortens routes and flight paths will save fuel.

Slide 13: Explain that reducing aircraft fuel consumption is the best way to reduce aircraft emissions. Discuss any ideas the students have for strategies to reduce aircraft emissions and aircraft noise.

Slide 14: Many technologies and innovations are being employed or under development to reduce aviation emissions. In the first semester, students learned about composites as a way to reduce aircraft weight and, thereby, fuel consumption. Also in the first semester, students learned that the Wright Brothers used wing warping (changing the shape of the wing) to achieve aircraft control. Today, wing warping (or morphing) is being studied as a way to reduce fuel consumption.

Later in the lesson, students will conduct independent research on an emerging technology aimed at improving aviation's environmental record.

This will conclude the first session.

EXPLAIN

Teacher Material: Reducing Aviation's Environmental Impact Presentation
Student Material: Reducing Aviation's Environmental Impact Student Activity 1

Slide 15: Aircraft noise is also a form of pollution and can result in negative consequences. To begin the second session of this lesson, ask students why aircraft noise is considered an environmental issue.

Questions

Why is aircraft noise considered an environmental issue?

Aircraft noise emitted into the environment can affect the quality of life for communities near airports. Like emissions, noise is commonly considered a form of pollution that can impact health and behavior and can cause hearing loss, sleep deprivation, hypertension, etc. Noise pollution also can affect animals.

Teaching Tips

Noise pollution may not be an environmental concern that students know. If needed, provide some context about how noise pollution can affect various groups and health conditions.
https://www.environmentalpollutioncenters.org/noise-pollution/

Slide 16: There can be health-related consequences of exposure to noise from aircraft. For example, cardiovascular effects may arise as a consequence of stress caused by noise, sleep patterns may be disturbed, and noise-related

annoyance can cause negative emotions. Noise also can disrupt routine activities, such as listening to the radio or television, talking on the telephone, or conducting a conversation in a home, classroom, or workplace.

Studies have been done on how aircraft noise might affect an animal's ability to react, hunt and forage, communicate, and reproduce.

Slide 17: Over the years advancements in airframe design and engine construction technologies have reduced airplane noise. Students will learn how engine chevrons reduce noise during a hands-on activity in this session.

To reduce aircraft impact on communities surrounding airports, approaches are being optimized to fly over water, highways, and less-populated areas as much as practical.

In addition, a video shows students how NASA is seeking ways to reduce aircraft noise by using massive supercomputers to model airflow.

- "NASA's Supercomputer To Cut Aircraft Noise" (Length - 7:14) http://video.link/w/tILd

Slide 18: The chevron is the sawtooth pattern that is seen on the trailing edges of some jet-engine nozzles. As hot air from the engine core mixes with cooler air blowing through the engine fan, the shaped edges serve to smooth the mixing, which reduces turbulence that creates noise.

Teaching Tips

To help students better understand chevron design, show the video:

- "V Shaped Design Makes for Quieter Aircraft" (Length 3:29) http://video.link/w/vILd

Slide 19: In the next hands-on activity, students will use engineering practices to create and evaluate a chevron design to reduce noise from the end of the thunder drum.

To begin, demonstrate how a thunder drum works. As they listen to the sound coming from the drum, have students draw what they think the sound waves that are being generated by the wire spring look like. They should include arrows that show the direction of the sound waves, including the sound waves both inside the drum and when they leave the drum.

Slide 20: Using engineering practices, students will design, create, and test chevron designs in small groups. Their goal is to reduce the sound emanating from the thunder drum. Provides copies of **Reducing Aviation's Environmental Impact Student Activity 1** to guide students through the activity.

Slide 21: Before students design their chevrons, review the engineering practices engineers use to solve problems and create new designs.

Remind students that engineers engage in three main activities during their practice: thoroughly examine the problem, create solutions and explanations, and continually assess the results.

Engineering practices support these activities by continuing to apply questioning, reasoning, and analysis iteratively and fluidly across all three.

- Defining problems
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data

- Using mathematics and computational thinking
- Designing solutions
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

Slide 22: If time allows, have each student team give a three-minute presentation to the class about their chevron designs. They should include their definitions of the problem, the model(s) used and data obtained, and how they interpreted the data and made adjustments.

After each presentation, allow a few minutes for critical discussion and comments. This activity will conclude the second session of this lesson.

EXTEND

Teacher Material: Reducing Aviation's Environmental Impact Presentation
Student Material: Reducing Aviation's Environmental Impact Student Activity 2

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

Formative Assessment

Working in small groups, students will explore and research an emerging technology aimed at improving aviation's environmental record.

Provide each student a copy of **Reducing Aviation's Environmental Impact Student Activity 2**. Have students select one of the two major categories of aviation's impact, select an emerging technology aimed at improving aviation's environmental record in that category, and complete research about the technology.

To ensure a variety of topics are researched and reported, teachers may want to assign topics to each group. Topics may include: winglets, composite airframes and structures, biofuels, wing warping or wing morphing, and turbofan engines.

Students (individually or in small teams) will give two- to three minute presentations on their chosen technologies. Other students should take notes on the innovations, their descriptions, how will improve aviation, and what challenges exist in its development.

[DOK 4; *explain, analyze*]

EVALUATE

Teacher Material: Reducing Aviation's Environmental Impact Presentation

Slide 24: Conduct the **Summative Assessment.**

Summative Assessment

Throughout this lesson, students have learned about ideas to reduce aircraft emissions and noise. In this summative assessment, students will make judgments about the relative value of the innovations being developed to reduce aviation's environmental impact.

Students should put themselves in the position of an airline executive who has both budget priorities and corporate social responsibilities. Imagining themselves in this role, students must pick the emissions- or noise-reducing technology they think holds the most promise for reducing aviation's environmental impact while being affordable to purchase or implement.

In several paragraphs, students should write which technology they would choose, explain why they think the technology holds such promise, and why they think it would be reasonable and feasible to buy or implement.

Summative Assessment Scoring Rubric

Follows assignment instructions

Student writing shows evidence of the following:

- An understanding of aviation's environmental impact from aircraft emissions and/or noise
- An understanding of the relative merits of their chosen technology and the others being developed

Student design shows in-depth thinking, including analysis or synthesis of lesson objectives

Student writing includes an organized explanation with correct grammar and spelling

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

GOING FURTHER

Students can explore zero-carbon aircraft and determine if this seems like a realistic pathway for reducing aviation's impact on the environment in the future.

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-ETS1-3** – 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

- **RL.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
- **RL.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.
- **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.

REFERENCES

https://www.faa.gov/regulations_policies/policy_guidance/envir_policy/media/Primer_Jan2015.pdf
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