Development of the Jet Engine

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 do technological advancements affect humankind?
2. How do jet engines work?
3. What are the advantages and consequences of flying high and fast?

LEARNING GOALS

Students Will Know

- The early challenges in the development of jet engines.
- The components and basic operation of a jet engine.
- The advantages of jet engines over piston engines.

Students Will Be Able To

- *Identify* and *describe* features of jet aircraft that came about as a result of jet engines. (DOK - L1)
- *Explain* how Newton's Third Law relates to the creation of thrust from a jet engine (DOK - L3)
- List and describe the main components of a jet engine (DOK - L1)

ASSESSMENT EVIDENCE

Warm-up
Students answer four questions to gauge their understanding of the basics of jet engines.

Formative Assessment
Students will complete scientific investigations of the components of a jet engine and how those components function and they will answer questions about their observations.

Summative Assessment
Students will write about the components of a jet engine, how the invention of the jet engine was a great turning point for aviation and how it impacted aircraft design.

LESSON PREPARATION

MATERIALS/RESOURCES

- Development of the Jet Engine Presentation
- Development of the Jet Engine Teacher Notes
- Development of the Jet Engine Teaching Aid 1
- Development of the Jet Engine Teaching Aid 2
- Development of the Jet Engine Student Activity

Jet Engine Lab Activity (per class)

Intake Station

- One desk fan
- Sheets of paper

Compression Station

- Two desk fans
- Six-inch pieces of string
- Index cards
- Tape
- Markers
- Paper clips

Combustion Station

- 250-500 milliliter Erlenmeyer flask
- Balloon
- Can of sterno/heat source
- Matches or lighter
- Tongs
- Heat/oven mitts
- Timer
- Safety goggles

Jet Engine Schematic Activity (per student)

- One paper towel or toilet paper tube (approximately 4-inches long)
- One flexible straw
- One 12x12-inch sheet of aluminum foil
- Four paper circles 1 12 inches in diameter
- One small paper clip

- One three-ounce paper cup
- Scissors
- Tape
- White glue

LESSON SUMMARY

Lesson 1 Development of the Jet Engine
Lesson 2 Commercial Air Travel

This lesson will be completed over three sessions. As a warm-up, teachers will lead an informal discussion in order to understand the student's basic knowledge of jet engines. Teachers will then lead students through a short activity to introduce the connection between Newton's Third Law (for every action, there is an equal and opposite reaction) and how a jet engine produces thrust.

A class discussion will teach students about the development of jet engines, how they have evolved since their invention and the different types of applications for which they are used. A homework assignment will ask students to complete research on how the jet engine impacted jet aircraft design.

In session two, students will learn how a jet engine operates and they will engage in scientific investigations to develop an understanding of the components of a jet engine and how those components function.

In session three, students will extend what they've learned by building their own jet engine schematics.

BACKGROUND

Sir Frank Whittle and Dr. Hans von Ohain are both recognized as being the co-inventors of the jet engine, even though each worked separately and knew nothing of the other's work.

Whittle was the first to register a patent for the turbojet engine in 1930, but Von Ohain is considered the designer of the first operational turbojet engine. It was von Ohain's jet that was the first to fly in 1939. Whittle's jet took off for the first time in 1941.

Please refer to **Development of the Jet Engine Teacher Notes** for background on how a jet engine works.

DIFFERENTIATION

To support verbal reasoning in the class discussion, organize the class into groups for Think-Pair-Share instead of a whole group discussion. This allows learners to think about the question and discuss their thoughts with a partner before sharing with the larger group. It encourages all students to participate and practice skills, including metacognition.

To promote reflective thinking and guided inquiry in the **EXTEND** section of the lesson plan, circulate around the classroom and assist students who might have trouble thinking through their observations and predictions. Ask questions that provoke their own ideas for possible answers.

LEARNING PLAN

ENGAGE

Teacher Material: Development of the Jet Engine Presentation

Slides 1-3: Introduce the topic and learning objectives for today's lesson.

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

[DOK1; state, recall]

Warm-Up

Lead a class discussion about each of the following questions. Ask students to explain their reasoning.

1. All planes need propellers to fly. True or false?

   False. Most modern aircraft use jet engines rather than propellers. Some aircraft use a jet engine to turn a propeller. This is called a turboprop.

2. Jet engines were developed mainly for mass transportation. True or false?

   False. The first jet engines were used on war airplanes.

3. Where did initial development of jet engines occur?

   Britain led the development of jet engines. Germany was the first to use them (on a World War II fighter).

4. How did the development of jet engines impact society?

   We can go faster and farther than ever before; jet engines changed the way wars are fought; commercial air travel is faster and more accessible because of increased performance and decreased cost.

EXPLORE

Teacher Material: Development of the Jet Engine Presentation

Slide 5: Lead students through a short activity to introduce the connection between Newton's Third Law (for every action, there is an equal and opposite reaction) and how a jet engine produces thrust. Students will revisit this concept in the **EXTEND** section of the lesson.

Blow up a balloon and hold it up. Ask students to predict what will happen when you let it go. Task students to make observations as you perform the demonstration. Give students a minute or two to discuss their observations.

Questions

What happened? Why do you think it happened?

Possible responses:

Sir Isaac Newton's Third Law states that for every action (force), there is an equal and opposite reaction. In other words, if an object exerts a force on another object, then the second object exerts an equal and opposite force on the first one. A jet engine produces thrust through action and reaction. The engine produces hot exhaust gases, which flow out the back of the engine. In reaction, a thrusting force is produced in the opposite direction.

Teaching Tips

Optional Approach: You may place students in pairs or small groups to do Think-Pair-Share to help them answer these questions.

EXPLAIN

Teacher Material: [Development of the Jet Engine Presentation]

Slide 6: Show a video describing the history of the development of the jet engine.

- "Jet Engine History" (Length 8:36)
  https://video.link/w/fAjWc
- For teachers unable to access video.link links, the YouTube video link is https://www.youtube.com/watch?v=8aZjG8F2Yj4

Slide 7: Sir Frank Whittle and Dr. Hans von Ohain are both recognized as being the co-inventors of the jet engine, even though each worked separately and knew nothing of the other's work.

Whittle was the first to register a patent for the turbojet engine in 1930, but Von Ohain is considered the designer of the first operational turbojet engine. It was von Ohain's jet that was the first to fly in 1939. Whittle's jet took off for the first time in 1941.

Slide 8: Ask students to consider several questions about the development of the jet engine.

Questions

Why was there a need to develop engines that would increase the distance and speed of aircraft?

Possible responses: to make travel for people and products faster and more efficient; to connect the world; to get a warfighting advantage.

What were the early challenges to making an operational jet engine?

Possible responses: finding materials that were suitable for handling the stress involved in operating a jet engine (mainly heat and pressure); effectively managing the challenges of high altitude flight.

Teaching Tips

Optional Approach: You may place students in pairs or small groups to do Think-Pair-Share to help them answer these questions.

Slides 9-10: Discuss how jet engines have evolved since their invention and the different types of applications for which they are used. Military applications will be discussed first, followed by civilian applications.

Slide 11: Introduce **Homework Assignment.**

Homework Assignment

As a homework assignment, ask students to complete research on how the jet engine impacted jet aircraft design. Jet engines allowed aircraft to fly much higher (where the air is colder and thinner) and at much faster speeds. Students should consider the consequences for aircraft design of using jet engines compared to the traditional piston engine.

Students should identify and describe at least three features of jet aircraft that came about as a result of jet engines. Possible findings could include swept wings, pressurization or the need for ejection seats in fighter aircraft.

EXTEND

Teacher Materials: Development of the Jet Engine Presentation, Development of the Jet Engine Teaching Aid 1, Development of the Jet Engine Teaching Aid 2

Student Material: Development of the Jet Engine Student Activity

Slide 12: Explain to students that in this session, they will learn more about how a jet engine operates. Remind them of the balloon demonstration from session one, and ask them to keep Newton's Third Law in mind as they work through this session's activity.

Slide 13: Show students a video that explains the operation of a jet engine and its main components.

- "How a Jet Engine Works" works. (Length 5:20)
  http://video.link/w/yLJd

Slide 14: Lead students through an activity called **"Jet Engine Lab."** Consult **Development of the Jet Engine Teaching Aid 1** for assistance in setting up the lab. Students will need copies of **Development of the Jet Engine Student Activity.**

Students will engage in scientific investigations to develop an understanding of the components of a jet engine and how those components function. They will gain a better understanding of how a jet engine takes in air, compresses it and combusts it.

This activity will conclude the second session of this lesson.

Slides 15: Conduct the **Formative Assessment.**

[DOK 3; compare, investigate]

Formative Assessment

Have students work in pairs to complete the Jet Engine Lab activity; however, each student should turn in their own copy of the Jet Engine Lab Activity.

After the students complete observations for each station in the lab activity, lead them through the following questions.

Lab Discussion Questions

What did you observe at the intake station? Did it match your prediction?

Possible responses: The paper held in front of the fan was blown away from the fan. The paper held behind the fan was pulled toward the fan. The paper at the back of the fan simulated the intake of air at a jet engine's inlet.

At the compression station, what did you predict would happen when both fans were turned on versus just the first fan? What actually happened?

Possible responses: The string will move higher on the card when both fans are blowing. The first fan will use suction to take in air. That air will increase in pressure as it passes through the first fan. The air from the first fan will increase again as it passes through the second fan.

What happened to the balloon in the combustion station? Why do you think that happened? What would happen if the air was enclosed in a tube (like inside a jet engine) that didn't expand like a balloon?

Possible responses: The balloon inflated because the air inside was heated. When air molecules are heated, they move faster and expand. In the balloon, this is shown as the balloon increasing in size, but when in a rigid container (or a tube like the combustor in a jet engine), the air pressure increases and escapes at a higher velocity. In a jet engine, this higher-velocity air drives the turbine component and then provides thrust by exiting the exhaust section at high speed.

All of these stations demonstrate the processes that take place inside various parts of a jet engine. In what order do you think they take place and why?

Possible responses: The proper order of the stations is intake, compression, and combustion. The two additional components of a jet engine are the turbine and the exhaust. These were not demonstrated.

Slide 16: Explain to students that in this session, they will reinforce what they've learned about how a jet engine works by building their own schematic.

Slide 17: Consult **Development of the Jet Engine Teaching Aid 2**. Students will incorporate lessons learned from the previous investigation to construct a jet engine schematic. This activity works best if completed individually.

Teaching Tips

You may want to set up the investigation with the following video, which will support what students how learned so far about the construction of a jet engine.

- "How a Jet Engine Works" (Length 3:56)

  http://video.link/w/0LJd

Slides 18-26: The slides provide a step-by-step guide to the construction of the schematic and can be used to guide students through the steps of building their schematics.

EVALUATE

Teacher Material: Development of the Jet Engine Presentation

Slide 27: Conduct the **Summative Assessment.**

Summative Assessment

Have students write three to four paragraphs in response to the following:

1. List and describe the five main components of a jet engine.
2. Explain how the invention of the jet engine was such a great turning point for aviation.
3. How did the jet engine impact aircraft design after its invention?

Use the Scoring Rubric for grading. [DOK-L4; explain, DOK-L1, define]

Summative Assessment Scoring Rubric

Follows assignment instructions

Answers show evidence of one or more of the following:

- Knowledge of the components and basic operation of a jet engine
- The advantages of jet engines over piston engines
- Advancement in aircraft design and capabilities after the jet engine was introduced

Answers show an in-depth understanding of the concepts covered in the lesson

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

Have students research the different types of jet engines (turbojets, turboprops, ramjets, etc.)

Teach students how a jet engine starts using this webpage from BoldMethod: http://www.boldmethod.com/blog/expressjet/how-a-jet-engine-starts-on-a-erj-145/

Two long videos/shows on jet engine aircraft to show students if time allows:

- Modern Marvels – Jet Engines (Length 44:11) http://video.link/w/4LJd
- Frontiers of Flight – Jet Power (Length 49:20) http://video.link/w/6LJd

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** - 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

- **HSG.MG.A.1** - Use geometric shapes, their measures and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).
- **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.
- **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.
- **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

https://www.nasa.gov/pdf/382712main_ETE_Lesson_1_Jet_Propulsion.pdf https://www.grc.nasa.gov/www/k-12/UEET/StudentSite/engines.htm https://www.thoughtco.com/history-of-the-jet-engine-4067905 https://cs.stanford.edu/people/eroberts/courses/ww2/projects/jet-airplanes/planes.html http://www.lockheedmartin.com/us/aeronautics/skunkworks/origin.html https://www.britannica.com/technology/history-of-flight/The-jet-enters-the-civilian-world https://cs.stanford.edu/people/eroberts/courses/ww2/projects/jet-airplanes/planes.html