CHRONICLES OF COURAGE
Stories of WARTIME AND INNOVATION

"Bf 109"

STEM Lesson Plan for Grades 7-12
Developed by the National Science Teachers Association
Access the Videos at NBCLearn.com/courage

"In personally facing the RAF in the air over the Dunkirk encirclement, I found that the Bf 109 E was faster, possessed a higher rate of climb, but was somewhat less maneuverable than the RAF fighters. "— Herbert Kaiser, German fighter ace. 68 victories

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Video Preview

"Bf 109," is one of 20 short videos in the series *Chronicles of Courage: Stories of Wartime and Innovation.* Toward the end of World War II, Allied forces led by the United States and Great Britain have broken through most Nazi defenses in Europe. Germany's last hope is their air force, known as the Luftwaffe, and their most trusted plane: the Messerschmitt Bf 109. Introduced in 1935, the Bf 109 was the first modern fighter, with all-metal construction, enclosed cockpit, and retractable landing gear.

Time	Video Content
0:00–0:16	Series opening
0:17–0:40	Allies advance into Germany
0:41–0:55	Pilot Ernst-Dieter Bernhard is given a dangerous mission
0:56–2:05	Pride of the Luftwaffe
2:06 –3:00	A strong but light airframe
3:01–3:57	Defending the bridge
3:58–5:10	Summary
5:22–5:36	Closing credits

Video Voices—The Experts Tell the Story

By interviewing people who have demonstrated courage in the face of extraordinary events, the *Chronicles of Courage* series keeps history alive for current and future generations to explore. The technologies and solutions presented are contextualized by experts working to preserve classic aircraft technology.

- **Ernst-Dieter Bernhard.** Bernhard was born in 1924. He entered the Luftwaffe as an officer candidate in 1942 during World War II. He became a squadron leader and Jagdflieger, the German word for fighter pilot, and was promoted to lieutenant in 1944.
- **Dr. Rebecca Grant** is President and CEO of IRIS Independent Research. Dr. Grant earned her Ph.D. in International Relations from the London School of Economics. Through IRIS, she works on strategic planning for aerospace and government clients. She writes regularly for *Air Force Magazine* and has appeared on *The Military Channel*.

Find extensive interviews with Bernard and other WWII veterans online at Flying Heritage Collection.

Connect the Video to Science and Engineering Design

The Messerschmitt Bf 109 flew for the first time in 1935. It saw its first combat during the Spanish Civil War (1936–1939). Although World War I's Versailles Treaty prohibited military aviation in Germany, Hitler recognized the need for a state-of-the art air force, and German engineers set to work on creating a new type of airplane whose sole purpose was combat.

Structurally, the Bf 109 benefitted from monocoque (French for single shell) design, where the skin takes on part or all of the structural load. A full monocoque design relies on the skin of the plane to hold the structure together. In a semi-monocoque design, the skin is reinforced by the underlying structure in part of the plane. Both designs require much less internal framework.

The Bf 109 had small wings, which allowed it to perform best at high speeds and high altitudes. At slower speeds, the plane automatically deployed leading edge slats, which greatly enhanced the aircraft's maneuverability. The aircraft was powered by the Daimler-Benz DB 601, a 12-cylinder, liquid-cooled, inverted V12 engine equipped with direct fuel-injection that provided fuel to the engine even when the aircraft was flying upside down. The Bf 109's weight was minimized by reducing the number of parts it contained. The wing spars, engine mounts, and landing gear were all connected to a single, strong fire-wall located in front of the plane's cockpit. Unlike most liquid-cooled aircraft, it had two radiators that allowed it to sustain a great deal of damage and still bring its pilot home.

Related Concepts

- stressed skin
- skeleton
- monocoque
- semimonocoque
- stringers
- fuselage
- lode carrying member
- inverted V12
- direct fuel-injection
- negative g
- positive fuel feed
- float carburetor
- pressure
- efficiency
- fuel air mixture
- flush-riveted

Explore the Video

Use video to explore students' prior knowledge, ideas, questions, and misconceptions. View the video as a whole and revisit segments as needed. Have students write or use the bell ringers as discussion starters.

Time	Video Content	Bell Ringers
0:17–0:40	Allies break through Nazi defenses	Students might discuss the psychological impact of defending your country from opponents crossing your national borders.
0:41–0:55	Introduction to Ernst-Dieter Bernhard	Students might assess the impact Bernhard's statement regarding the lack of optimism would have on the effectiveness of his mission.
0:56–2:05	Last ditch effort to stop the allied advance	In addition to using attacks by fighter planes to destroy Remagen Bridge, the German arsenal included weaponry such as artillery, floating mines, jet aircraft, and V-2 rockets. Have students create drawings that highlight the variables involved in using one of these weapons to attack the bridge. Then have students compare and contrast their drawings.
2:06 –3:00	Introduction to the Bf 109	Students might identify how the Bf 109 features mentioned in this portion of the video contribute to Dr. Grant's final assessment.
3:01–3:57	The Bf 109's monocoque construction	The Bf 109 was designed to achieve minimal weight. Many of its components were "lightened" during its many iterations. Hard turns or heavy landings often resulted in corrugations in the aircraft's external skin. Students could show how they would identify/determine if this results from the monocoque construction or material defects. Spark students' interest with a quick demonstration. Using a flat of eggs with a board on top, have students take turns carefully standing on the board to show the strength of the eggs underneath. Less dramatic and less expensive is to put a few eggs in a bowl and place a thick book on top.
3:58–5:10	Heaviest concentration of anti-aircraft guns in the war	Americans defended the air over the Remagen Bridge against 367 attacking German aircraft. During the 10 days of the battle, 109 of these aircraft were shot down. Students might determine the mathematical chance that Bernhard had to complete his mission.
5:11–5:21	Summary	Although not mentioned in the video, the bridge

		collapses 10 days after the Allies capture it. In those 10 days, 25,000 troops and thousands of vehicles cross the bridge into German territory. Students might identify and support a claim for why the bridge failed.

Language Support
To aid those with limited English proficiency or others who need help focusing on the video, make available the transcript for the video. Click the TRANSCRIPT tab on the side of the video window, then copy and paste into a document for student reference.

Explore and Challenge

After prompting to uncover what students already know, use video for a common background experience and follow with a minds-on or hands-on collaboration.

1. Explore readiness to learn from the video with the following prompts:
    - *Characteristics of a good fighter plane include….*
    - *It is beneficial for an aircraft to be as strong and light as possible because…*
    - *The skin, or outer covering of an aircraft, serves as….*
2. Show the video and allow students to discuss their observations and questions. The video highlights the Bf 109, which was among the most advanced fighter aircraft of its era. More Bf 109s were made than any other fighter plane—almost 34,000. Constant development kept the Bf 109 competitive with Allied planes through the end of World War II. Elicit observations about the aircraft presented and how its technology and innovations helped it to successfully complete its missions.
3. Explore understanding with the following prompts:
    - *Scientific knowledge that would aid in destroying a bridge across a wide river might include….*
    - *Features of a "modern" 1940s aircraft include….*
    - *Monocoque and stressed skin design helps to support….*
    - *Variables associated with low-altitude ground attack versus high-level bombing include….*
4. Help students identify a challenge, which might be based on the questions they have. Teams should focus on questions that can be answered by research or an investigation. Possible activities that students might explore are offered in *Identify the Challenge*.

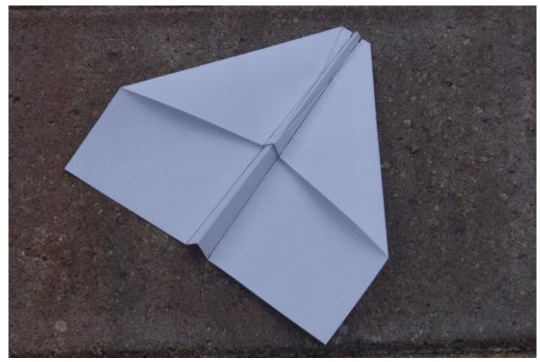
Identify the Challenge

Stimulate small-group discussion with the prompt: *This video makes me think about….* Encourage students to think about what aspects of the aircraft/technology shown in the video helped ensure a successful completion of its mission. If needed, show the video graphic comparing a Bf 109 with an egg (3:01–3:57) as a way to spark ideas or direct student thinking along the following lines.

- Students might determine if a monocoque or semi-monocoque design is stronger based on weight.

- Students might design and build a paper airplane that successfully mimics a semi-monocoque design. To do so, students could add supports such as straws or toothpicks to the fuselage part of the plane. Then students could compare it to a monocoque version of the same basic structure.
- The Bf 109's design was famous for mounting of all structural points to a strong firewall at the front of the cockpit, including the wing spars, engine mounts, and landing gear. Students could demonstrate why this concept results in an efficient aeronautical design.

  An example of a possible design that reflects monocoque, which has no supports in the fuselage area, might look like this:

Ask groups to choose their challenge and rephrase it in a way that it can be explored through elaborations on a classic paper airplane or through research or other investigative methods. If students choose to investigate with paper airplanes and need more support, they might use one of these resources.

- Paper airplanes
- 10 of the best paper plane designs
- Secret paper aeroplanes
- Paper airplane aerodynamics
- Styrofoam glider

Investigate, Compare, and Revise

Remind students that their engineering design challenges connect to real-world problems and usually have multiple solutions. Each team should be able to explain and justify the challenge they will investigate using concepts and math previously learned. Approve each investigation based on student skill level and the practicality of each team completing an independent investigation. Help teams to revise their plans as needed.

Assemble Equipment and Materials

Many materials can be found in a classroom to help students investigate challenges such as those suggested in *Identify the Challenge*. Suggestions include:

- square and rectangular sheets of paper of various thicknesses
- paperclips
- scissors
- tape, clear and masking
- string or fishing line
- glue
- measuring tape
- ruler
- protractor
- calculator

- plastic foam plates
- bamboo skewers or other light wooden supports
- cell phone camera
- sticky notes
- drinking straws of various diameter

Manipulate Materials to Trigger Ideas: Allow students a brief time to examine and manipulate available materials. Doing so aids students in refining the direction of their investigation or prompts new ideas that should be recorded for future investigation. Because conversation is critical in the science classroom, allow students to discuss available materials and change their minds as their investigations evolve. The class, as a whole, can decide to exclude certain materials if desired. Placing limitations on the investigations can also be agreed to as a class.

Consider having students record their initial observations and thoughts in their science notebooks. Encourage them to write down questions, ideas, and terms that come to mind and make simple sketches. This will lead to ideas for exploration.

Safety Considerations: Foster and support a safe science classroom. While investigating students should follow all classroom safety routines. Review safe use of tools and measurement devices as needed. Augment your own safety procedures with NSTA's Safety Portal.

Investigate

Determine the appropriate level of guidance you need to offer based on students' knowledge, creativity, ability levels, and available materials. Provide the rubric found at the end of this lesson plan to students prior to the activity and review how it will be used to assess their investigations.

Guide the class as a whole to develop two or three criteria for their investigation at the outset. You or your students might also identify two or three constraints. One major constraint in any design investigation is time. Give students a clear understanding of how much time they will have to devise their plan, conduct their tests, and redesign.

Present/Compare/Revise

After teams demonstrate and communicate evidence-based information to the class about their findings and reflect on the findings of other groups, allow teams to make use of what they have learned during a brief redesign process. Encourage students to identify limitations of their investigative design and testing process. Students should also consider if there were variables that they did not identify earlier that had an impact on their results. It is also beneficial to discuss any unexpected results. Students should quickly make needed revisions to better meet the original criteria, or you might make suggestions to increase the difficulty of the challenge.

Pushing the Envelope

While aircraft are the primary benefactors of monocoque and semi-monocoque design, a few other vehicles use that design as well. Some tanks and race cars are built with a strong structural skin so that internal framework isn't needed. Some rockets and speed boats use the design as well. Students might find technical drawings of such vehicles during an Internet search and create a short presentation that compares them to aircraft designs.

Both Germany's Bf 109 and Britain's Supermarine Spitfire were notorious for landing problems created by the designs of their landing gear. The Bf 109 and Spitfire, in contrast to later designs, had their landing gear attached close to the point where the wings meet the fuselage, resulting in a thinner, lighter wing. This placed the landing gear wheels close together directly underneath the fuselage. Future designs would have the landing gear incorporated into the wing design, leading to a heavier wing that provided more stability when landing and taxiing the aircraft.

Students might research these problems and how other landing gear systems have been designed to offer routine safe landings.

Build Science Literacy THROUGH READING AND WRITING

Integrate English language arts standards for college and career readiness to help students become proficient in accessing complex informational text.

INTEGRATE INFORMATIONAL TEXT WITH VIDEO

Use the video to set the context for reading and writing. Then, provide students access to scientific or historical texts such as these. *NOTE: At times, fighter pilots use colorful language when describing the terrible events that took place in war. Review the first two texts for appropriateness in your teaching situation.*

- Flying the Messerschmitt Bf-109
- Daimler-Benz DB 601
- Semi monocoque, mono-what?
- Messerschmitt 109
- Flying upside down

You can also find interviews with many WWII veterans online at Flying Heritage Collection. Encourage students to use search words to find the key ideas they are looking for or specific veterans who talk about those ideas. If students would benefit from a hard copy of the transcript or portions of it, triple-click on the transcript to copy-and-paste.

WRITE You might give students a writing assignment that allows them to integrate the text(s) and video as they write about an aspect of all the information they will examine. Students should cite specific support for their analysis of the science and use precise details and illustrations in their explanations and descriptions. Examples of writing prompts that integrate the video content with the text resources cited above include the following:

- Students might write to explain interesting aspects of the Bf 109's landing gear from a scientific point of view.
- Students could write an advertisement that scientifically extolls the benefits offered by the Daimler-Benz DB 601.
- Students might select another World War II aircraft and compare and contrast the design of its fuselage with that of the Bf 109.

READ Any good piece of writing must be carefully planned. Its internal segments must work together to produce meaning. According to Tim Shanahan, former Director of Reading for Chicago Public Schools, students must do "an intensive analysis of a text in order to come to terms with what it says, how it says it, and what it means."

Encourage close reading using strategies such as the following to help students identify the information they will use to develop a selected topic. For background on close reading, see the ASCD resource Closing in on Close Reading. As with any Close Reading Strategy, these strategies will be more helpful if students read the text more than once.

Highlight and Circle. Have students use a highlighter to mark sentences in which the author makes a claim or offers data to support a position. Students could circle key terms that are found throughout the text or are defined by the author.

Plot a Movie Trailer. As students read they could think of a potential video trailer that could be used to promote the reading to other students. In order to adequately complete this task, students must have a firm grasp of the main idea and supporting details. They must also address the problem identified in the video and text and how that problem was overcome so that the mission could be accomplished. Historical perspective should play a role in student trailers. Have students list items that have to appear in their trailers as they read.

Summary Activity

Increase retention of information with a brief, focused wrap-up.

Have students quickly make a list of bulleted key points that fully identify the design features of the Bf 109. You might have students create this checklist in parallel columns, using one for the bulleted design feature and the other for how those design features enable to meet the criteria of its performance.

NATIONAL STANDARDS CONNECTIONS

Next Generation Science Standards

Visit the online references to review the supportive Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts for these connected Performance Expectations.

MS-PS2 Motion and Stability: Forces and Interactions

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.

MS-PS2-4. Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.

MS-PS3 Energy

MS-PS3-1. Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.

MS-PS3-5. Construct, use, and present arguments to support the claim that when the motion energy of an object changes, energy is transferred to or from the object.

MS-ETS1 Engineering Design

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

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.

Common Core State Standards for ELA & Literacy in Science and Technical Subjects

Visit the online references to find out more about how to support science literacy during science instruction.

College and Career Readiness Anchor Standards for Reading

1. Read closely to determine what the text says explicitly and to make logical inferences from it; cite specific textual evidence when writing or speaking to support conclusions drawn from the text.
6. Assess how point of view or purpose shapes the content and style of a text.
7. Integrate and evaluate content presented in diverse formats and media, including visually and quantitatively, as well as in words.
8. Delineate and evaluate the argument and specific claims in a text, including the validity of the reasoning as well as the relevance and sufficiency of the evidence.

College and Career Readiness Anchor Standards for Writing

1. Write arguments to support claims in an analysis of substantive topics or texts using valid reasoning and relevant and sufficient evidence.
2. Write informative/explanatory texts to examine and convey complex ideas and information clearly and accurately through the effective selection, organization, and analysis of content.
7. Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.
8. Gather relevant information from multiple print and digital sources, assess the credibility and accuracy of each source, and integrate the information while avoiding plagiarism.
9. Draw evidence from literary or informational texts to support analysis, reflection, and research.

ASSESSMENT RUBRIC FOR INQUIRY INVESTIGATION

Criteria	1 point	2 points	3 points
Initial problem	Problem had only one solution, was off topic, or was not researchable or testable.	Problem was researchable or testable but too broad or not answerable by the chosen investigation.	Problem was clearly stated, was researchable or testable, and was directly related to the investigation.
Investigation design	The design did not support a response to the initial question or provide a solution to the problem.	While the design supported the initial problem, the procedure used to collect data (e.g., number of trials, or control of variables) was insufficient.	Variables were clearly identified and controlled as needed with steps and trials that resulted in data that could be used to answer the question or solve the problem.
Variables (if applicable)	Either the dependent or independent variable was not identified.	While the dependent and independent variables were identified, no controls were present.	Variables were identified and controlled in a way that resulting data could be analyzed and compared.
Safety procedures	Basic laboratory safety procedures were followed, but practices specific to the activity were not identified.	Basic laboratory safety procedures were followed but only some safety practices needed for this investigation were followed.	Appropriate safety procedures and equipment were used and safe practices adhered to.
Data and analysis (based on iterations)	Observations were not made or recorded, and data are unreasonable in nature, or do not reflect what actually took place during the investigation.	Observations were made but lack detail, or data appear invalid or were not recorded appropriately.	Detailed observations were made and data are plausible and recorded appropriately.
Claim	No claim was made or the claim had no relationship to the evidence used to support it.	Claim was related to evidence from investigation.	Claim was backed by investigative or research evidence.
Findings comparison	Comparison of findings was limited to a description of the initial problem.	Comparison of findings was not supported by the data collected.	Comparison of findings included both group data and data collected by another resource.
Reflection	Student reflection was limited to a description of the procedure used.	Student reflections were related to the initial problem.	Student reflections described at least one impact on thinking.