CHRONICLES OF COURAGE
Stories of WARTIME AND INNOVATION

"The Doolittle Raid"

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

"If we should have to fight, we should be prepared to do so from the neck up instead of from the neck down." —Jimmy Doolittle

Table of Contents

Click the section title to jump to it. Click any blue or purple head to return:

Video Preview

"Doolittle Raid," is one of 20 short videos in the series *Chronicles of Courage: Stories of Wartime and Innovation.* Four months after the Japanese attack on Pearl Harbor, the United States launches a top-secret mission to bomb Japan. Led by Colonel James Doolittle, this risky assignment calls for American bomber planes to launch from an aircraft carrier in the sea—something that had never been done before.

Time	Video content
00:00–00:16	Series opening
00:17–01:11	Pearl Harbor attack led to a top secret mission to drop bombs on the Japanese homeland
01:12–01:31	Introduction to Lieutenant Colonel James Doolittle
01:32–02:55	The airplane and the demands of the mission
02:56–03:38	The weight limits of the mission
03:39–05:33	The mission
05:34–05:49	Summary
05:50–06:04	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 generations to explore. The technologies and solutions presented are contextualized by experts working to preserve classic aircraft technology.

- **Lieutenant Richard "Dick" Cole** was the co-pilot for James Doolittle. Cole graduated from high school in Dayton, Ohio and completed two years of college before enlisting in the military. He completed pilot training in July 1941 and served in the China-Burma-India Theater until June 1944.
- **Dr. Eric Sheppard** is the dean of the Hampton University School of Engineering and Technology. Sheppard's areas of interest include propulsion and power (particularly electromagnetic thrusters), design, analytical, and computational methods in fluid dynamics and aerodynamics. Sheppard has been elected an Associate Fellow by the American Institute of Aeronautics and Astronautics.

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

Connect the Video to Science and Engineering Design

After Japan's attack on Pearl Harbor, the United States set a plan in motion to take the battle to Japan's homeland. However, America's aircraft were unsuited for the mission as their combat range was only about 300 miles. Putting U.S. aircraft carriers this close to Japan put them at risk of attack from land-based aircraft. The mission planners had to find larger, heavier aircraft that could carry the fuel they needed in order to launch from a greater distance and still make it to Japan, as well as take off with only 500 feet of runway—the length of a carrier deck. The B-25 was the answer—with some modification.

Once properly aligned to the runway, an aircraft's pilot uses the throttle to increase engine power and accelerate down the runway. This forward motion causes air to pass more quickly over the curved surface of its wings, creating lift. Once sufficient airspeed and lift are attained, the aircraft leaves the ground. Pilots call this "rotation speed," abbreviated V_r which is one of several variants on velocity (V) that pilots need to know. The weight of an aircraft determines how much lift and speed are required to get it off the ground.

The amount of lift an airplane generates depends on the shape and size of its wings. The angle at which its wings meet the air flowing around them (angle of attack) also impacts the amount of lift the wings can deliver. Air temperature and density are other variables that affect V_r. Of course, the power of an aircraft's engine will impact how quickly the aircraft will get to V_r.

Related Concepts

- acceleration
- speed
- air flow
- lift
- rotation speed
- angle of attack
- stall speed
- lift coefficient
- torque
- horsepower

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
00:17–01:11	Pearl Harbor attack led to a top secret mission to drop bombs on the Japanese homeland	Before showing the clip, pose the following questions: Why did the Japanese military believe it was important to bomb Pearl Harbor? What impact did the bombing of Pearl Harbor have on America? What technological challenges must be overcome to bomb a very distant target?
01:12–01:31	Introduction to Lieutenant Colonel James Doolittle	Students might come up with three to five questions that they would like to ask a legendary speed pilot and aviation engineer.
01:32–02:55	The airplane and the demands of the mission	After viewing the clip, students might identify the variables that had to be controlled in order for a B-25 twin-engine bomber to take off from an aircraft carrier's deck. What variables could not be controlled?
02:56–03:38	The weight limits of the mission	The B-25 Mitchell was over 50' long and had a wingspan of almost 70'. Its empty weight was around 20,000 pounds. The U.S.S. *Hornet's* main scout and dive-bomber aircraft was the Douglas SBD, which was 33' long with a wingspan of 41' and that had an empty weight around 6,400 pounds. Students might analyze these numbers and draw conclusions about the two planes' take-off capabilities.
03:39–05:33	The mission	Share with students that on April 18, 1942 as the B-25s were launched, the U.S.S. *Hornet* was sailing at best speed into a 30-knot headwind. The forward movement of the carrier into the headwind resulted in a wind of 50 knots (almost 60 mph) into which the B-25s were launched. (Students should assume that the ship was sailing directly into the headwind.) Students might draw a diagram that will allow them to examine and explain this situation.
05:34–05:49	Summary	Teams of students might do research to determine the outcome of Doolittle's Raid. Did the knowledge gained impact other military operations? Were Army bombers ever again flown off aircraft carriers? Were future bombers constructed lighter for this purpose?

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:
   - *When dropping an object from a great height, variables that need to be considered include….*
   - *Something I know about the distribution of weight in an aircraft is…*
   - *The angle of attack of an aircraft's wings matter during the takeoff because….*
   - *Challenges presented by shortening the length of an aircraft's takeoff run include….*
2. Show the video and allow students to discuss their observations and questions. Because naval aircraft at the time did not have the needed range or bomb load capacity, the U.S. Army Air Forces' North American B-25 Mitchell twin-engine medium bomber was flown off the aircraft carrier U.S.S. *Hornet*. The bomber had to be lightened in order to launch from the *Hornet*'s 500-foot runway. Elicit observations about the aircraft presented and how its technology and innovations helped it to be successful in its mission.
3. Explore understanding with the following prompts:
   - *A bombsight, a device used to calculate the path of a falling bomb, can improve targeting accuracy by….*
   - *When adding additional fuel tanks to increase an aircraft's fuel capacity, the location of the tanks must….*
   - *When shortening the length of an aircraft's take off run, its wing's angle of attack would ___ because….*
   - *Flying at low altitudes helps aircraft to avoid land based radar because….*
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 assure a successful completion of its mission. If needed, show the video segments 01:12–03:38 about the B-25 as a way to spark ideas or direct student thinking along the following lines.

- Students might choose to construct a light, well-trimmed paper airplane in which the angle of attack of its wings can be manipulated to determine the lowest launch speed at which it can take off without stalling.

- The fuel capacity of the B-25s in Doolittle's raid was increased by adding three additional internal fuel tanks and ten 5-gallon cans of aviation gas. Students might explore, using coins or other simulated weights, where these tanks can be located in an aircraft so that it can still fly in a controlled, balanced manner.

In addition, share with students that during World War II, all Army Air Force and Navy bomber aircraft used the Norden bombsight. It offered advanced technology that could determine the aircraft's direction and ground speed. To lighten the aircraft and prevent the B-25's top-secret Norden bombsights from falling into enemy hands, they were removed from all 16 of the mission's aircraft. A replacement sight was built by mission pilot Charles Greening from some metal objects he had at the reported cost of about 20 cents.

  - Students might design and test their own low cost bombsight. They could securely suspend and move a cell phone below a taut line and use its camera as a guide for dropping an object on a grid placed below.
  - Students might explore trajectories of objects dropped from aircraft as a function of the speed at which the aircraft are moving.

Ask groups to choose their challenge and rephrase it in a way that it can be explored through elaborations on the classic paper airplane or creation of a system to investigate functionality of bombsights.

If students choose to explore navigation 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
- Launchable drinking straw planes

Investigate, Compare, and Revise

Remind students that 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
- drinking straws
- toothpicks
- scissors
- tape, clear and masking
- string or fishing line
- glue
- measuring tape
- ruler
- protractor
- calculator
- cell phone camera

- wire
- cylindrical weights
- sticky notes
- electric plane launcher (optional)

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.

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 to students 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

Engineers and aeronautical designers were intensely motivated by the devastating, ongoing impact of World War II. Most of the aircraft underwent iterative design improvements, resulting in different versions that had different capabilities.

Elicit from students the features of the B-25 that could be adapted for the mission presented in *Doolittle's Raid*. When practicing to fly their bombers off a simulated aircraft carrier deck painted on an airstrip, pilot Don Smith set the record when he hauled his bomber off the ground after only 287 feet! Have students conduct research and report on how modern aircraft are designed to deal issues such as:

- Varying lengths of runways at commercial airports.
- How bombsights have changed over the years.
- Balancing fuel capacity and loaded weight.

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. Then, provide students access to science scientific or historical texts such as these:

- Dick Cole—Last of the Doolittle Raiders
- James H. Doolittle—Flight/Mission Report
- The Impossible Raid
- How Airplanes and Aircraft Fly

You can also find interviews with Cole and many other WWII veterans online at Flying Heritage Collection. Encourage students to use search words to find the key ideas they are looking for.

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:

- Write a science article for a magazine that explains one the innovations that made the Doolittle Raid possible.
- Make and support claims about the capabilities of the B-25 Mitchell that would persuade your 'military superior' of its suitability for Doolittle's Raid.
- Explain, using science and aeronautical terminology, how a land based, medium bomber that weighed in at 20,000 was able to take off from an aircraft carrier.

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, the strategies will be more helpful if students read the text more than once.

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.

Word Choice. As students read, have them circle words that stand out. Then have them draw a line from the word to the nearest margin and explain how the word helps them to look at characters or event, evokes emotions, produce an effect, or have more than one meaning.

Summary Activity

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

Give students an index card. On one side have them write three things that they learned during the lesson. On the reverse side they could identify two things they still have questions about and one thing about the lesson that they want you to know.

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.