FUTURE U.

Welding Opportunities

Objectives

Students wil be able to:

- **Experiment** with and **simulate** a variety of bonds.
- **Explain** the process of welding and its importance in both the aerospace industry and the world at large.
- **Research a** specific welding career, **consider** the role it plays in the aerospace field, and **create** a presentation that informs others about this career path.

Lesson Overview

As our STEM capabilities increase and American infrastructure ages, welding has become one of the fastest growing professions in America. In fact, the American Welding Society predicts there will be a nationwide shortage of more than 450,000 welders by 2022. This lesson therefore guides students in exploring the field of welding as they pretend that they are part of Boeing's Early Career Rotational Program. During this "program", students will learn more about the science behind welding, explore its uses across manufacturing and aerospace, and ultimately prepare a presentation that highlights this career path for a middle school job fair!

This lesson focuses on

21st Century Skills

- Communication
- Collaboration
- Critical thinking
- Creativity

Timing

Three 45–60-minute class periods

Materials

ALL DAYS

- Computer or device with the ability to project, one for the instructor

DAY 1

- Devices with internet access, at least enough for half the class
- Image to project
- Four marble-sized pieces of clay, enough for half the class
- Small cups filled with water, enough for half the class
- Welding in Popular Culture video

- Images one, two, and three to project
- Welding Investigation handout (2 pages), enough for half the class

DAY 2

- Exploration Notes handout, one per student
- **Station 1**
    - "Welding Background" article, one per student
- **Station 2:**
    - Three or four devices, each prepared with the following two videos:
        - Welding Wonder
        - NASA Now
- **Station 3:**
    - At least 2 hot glue guns and glue
    - At least 2 staplers
    - At least 2 bottles of liquid glue
    - About 60 small pieces of cardboard or poster-board cut into approximately two-inch squares
- Career Fair handout (2 pages), one per student
- Your Welding Career Navi System article (page 4 only), one per student
- Devices with internet access, at least one per every three students

DAY 3

- Devices with internet access, at least one per every three students
- Career Fair Notes, one-half page per student

Have you ever wondered . . .

When did welding begin?

The earliest incidences of welding are believed to have occurred during the Bronze Age (3000–1200 BC) to construct pressure-welded gold boxes. During the Middle Ages, welders switched to a system called forge welding in which two pieces of metal were heated until they were bright red but not yet melted. Blacksmiths would then place the metals on an anvil and pound them together. The system was labor-intensive, but it allowed welding to occur without electricity![1]

What does welding look like today?

Welding is involved in the creation of a wide range of products, from smaller items like jewelry and household decorations to much bigger projects like skyscrapers, cars, planes, and even rockets! Today, welding has evolved into two main types: arc welding and torch welding. Arc welding is used most frequently in manufacturing. It relies on a power source to create an electrical arc between an electrode and the metals being bonded. Torch welding is used more frequently for non-industrial repair work and maintenance. In this type of welding, a torch melts the welding rod and metals simultaneously. Welding contributes to the production of roughly 50% of the United States' gross national product.[2]

Make Connections

How does this connect to students?

By 2022, the American Welding Society is predicting a nationwide shortage of more than 450,000 skilled welding professionals. However, the need for welding experts is only increasing, especially as infrastructure ages and new innovations are developed. This means that the scope of potential welding jobs for students is not only large but also varied—including careers in aerospace, automotive, shipbuilding, manufacturing industries, and more.[3]

While welding requires technical on-the-job experience, a four-year undergraduate degree is not usually necessary. Welding can therefore be an excellent career option for those looking for hands-on work, a reliable (and often lucrative) salary, and a career that focuses on practical experience over a college degree.[4]

How does this connect to careers?

Welding Technician: As the name implies, welding technicians are responsible for completing the actual welding work! People in this career apply their background and training to make important decisions about what type of welding techniques and equipment should be used before they begin welding.

Metal Fabricator: Metal fabricators may be responsible for creating one specific component of a larger product, or they may weld various components together into the finished product. This career differs from a welding technician because it is more focused on the overall product and not simply the welds.

Welding Engineer: Welding engineers design, review, and evaluate welds. They also plan and supervise welding operations to make sure they are in agreement with codes and contracts.

How does this connect to our world?

Not only are welded materials used all around the world, but they literally connect our world too! Welding contributes to technology, cars, bridges, ships, airplanes, energy, and even space. Welding helps make travel and global communication possible, and it even helps expand our horizons through its contributions to space travel.[5]

In addition, those who choose to be welders have the opportunity to work around the world. From boats at sea to construction sites and rocket ships, welders are needed in a wide range of industries. Some welders are even called traveling welders. These welders tend to specialize in one area, such as race cars, satellites, or underwater repairs, and then they travel around the world to where they are most needed![6]

Sources

1 "The History of Welding." Welder Portal. welderportal.com/the-history-of-welding

2 Atteberry, Jonathon. How Welding Works. HowStuffWorks. science.howstuffworks.com/welding.htm.

3 Rozyla, Lauren. "Tampa Bay Area Facing Shortage of Trained Welders." ABC Action News. abcactionnews.com/news/region-hillsborough/tampa-bay-area-facing-shortage-of-trained-welders.

4 "Welding Education Requirements and Career Information." study.com/welding_education.html.

5 "Welding Connects Our World." American Welding Society. youtube.com/watch?v=hbKICTA70TU.

6 "What Does a Traveling Welder Do?" ZipRecruiter. ziprecruiter.com/e/What-Does-a-Traveling-Welder-Do?

Blueprint for Discovery

DAY 1

1. Begin class by welcoming students to Boeing's Early Career Rotational Program and explain that as students pretend to be part of this program, they will learn about career opportunities at Boeing. Over the next few periods, the class will focus specifically on welding.
2. To kick off, divide students into pairs. Distribute four marble-sized pieces of clay to each pair, as well as a small cup of water.
3. Then project this image and explain that students are looking at a rocket fuel tank. Challenge student pairs to use their clay and water to create a miniature model of this tank. Tell students they will have about five minutes to complete the challenge.
4. After about five minutes have passed, bring the class back together and encourage pairs to display their models. Ask students to share how they joined their clay pieces and explain why/how water played an important role in the joining process. Ensure students understand that the water changed the state of the clay matter and helped "fuse" the different parts of their model together.
5. Explain that the actual rocket fuel tank was created in a somewhat similar manner: several pieces of metal material were fused together using heat. Tell students that this practice is called welding and ask students to give you a thumbs up if this term is familiar.
6. Activate students' prior knowledge by playing a minute or so of this *Welding in Popular Culture* video, and then ask for another round of thumbs up to see if any additional students recognized the concept of welding.
7. Toggle back and forth between these images (one, two, and three) to give students insight into what a product that has been fabricated or made through welding may look like. Encourage students to share their general observations as you flip through the images. Ensure students understand that when welding is used, it takes the place of screws, hinges, glue, etc. Welding is another way to join two pieces of metal. In a weld, at least two different pieces of metal become one.
8. Pass out a Welding Investigation handout to each pair and explain that this investigation will challenge students to consider how welding is used both throughout the school and in the world at large! Review the directions provided for Parts 1 and 2, and then give students about 20 minutes to complete the entire handout with their partner.

   Note: If pairs are not permitted to walk around the school themselves, you may complete Part 1 together by exploring the school as a class.
9. When the class is back together, encourage groups to share some of the different welding examples that they discovered for Part 1. Then review the class' answers to Part 2. The correct answers are as follows:

   1. Airplanes
   2. Automobiles
   3. Rockets
   4. Skyscraper
   5. Bridge
   6. Boats

10. Conclude the class session with a think-pair-share* around students' initial perceptions of welding. Based on what they have learned so far, does welding seem to play an important role in society? Why or why not?

    **Note:* In a think-pair-share, students think about the question independently, discuss their answers with a partner, and then share their thoughts with the larger class.

DAY 2

Instructor Prep: Before class begins, set up the three stations around the classroom with the supplies listed in the Materials section.

1. Welcome students back to Day 2 of Boeing's Early Career Rotational Program. Explain that now that students understand the range of products that welding can create, it is important to also understand what exactly welding is and how it connects to Boeing and aerospace.
2. Divide students into new groups of three or four and distribute an Exploration Notes handout to each student.
3. Explain that during the next twenty minutes, groups will be rotating through three stations. Be sure to share:
    - Each group will be assigned a station where they will begin.
    - The directions at each station are clear, so each group is expected to read the directions for each station carefully before they begin.
    - Once groups have completed all steps at a station, they may proceed to a new station. Groups may have to wait a minute or two to share materials at each station.
4. Assign each group a station where they will begin, and then encourage groups to get started. Rotate throughout the room as students work and answer questions as needed. Give students a five-minute warning when fifteen minutes have passed.
5. Once about 20 minutes have passed or students have completed each of the stations, bring the class back together and discuss these three focus questions as a class:
    - How does welding work?
    - How is welding used in aerospace?
    - Why may aerospace companies choose welding over other attachment methods?
6. Now that students have a better understanding of welding and its applications in aerospace, explain that the next part of the career program will be to share their knowledge by participating in a career fair at a local middle school.
7. Distribute one Career Fair handout and one "Your Welding Career Navi System" article to each student.
8. Then assign students one of the following welding careers:
    - welding engineer
    - welding fabricator
    - welding research scientist
    - welding supervisor
    - welding inspector
    - welding technician
    - robotic welding technician

9. Explain that students with the same career will work together to complete the Career Fair handout. Before students begin, review each of the steps on the Career Fair handout and answer questions as needed. Explain that students will have the remainder of this class period as well as half of next period to complete their research. They will then be responsible for sharing the work they complete in Step 4 during the last half of next session.
10. Assign different sections of the classroom for each career and encourage students to meet with the other "professionals" in their field and get to work. When the class period is over, remind students to save their work in a safe place, because they will need it for the next session!

DAY 3

1. As class begins, encourage students to continue their Career Fair preparation. Remind students that they will have half of the class period to complete their prep work.
2. When half of the class session is remaining, bring students back together. Form new groups of about seven students around the classroom and try to have each career represented in every group.
3. Explain that students are going to take turns presenting their careers to each other. As students present their careers, they should pretend that they have this job. While the rest of the group listens to each presentation, they should put themselves back into the shoes of a middle school student.
4. Pass out one Career Fair Notes handout to each student. Read the directions and explain that each student could select careers that sound intriguing, that they would like to explore further, or that they may like to try someday! Every student must select two careers.
5. Now it's time to kick off the Welding Career Fair! As students present, rotate from group to group and listen as students share.
6. When there are 10 minutes left in class, tell students that the Career Fair will wrap up in five minutes.
7. Finally, bring the entire class back together and congratulate students on successfully completing the welding rotation of Boeing's Early Career Rotational Program. Instruct them to return to being middle school students, and conclude by discussing the following questions as a full class from their "younger" perspective:
    - How does welding impact our daily lives?
    - How could welding impact (or contribute to) our future?

EXTEND

Students can perform additional research on the history of welding. They can focus especially on the presence of women in welding and investigate what the field is doing to attract more female welders!

National Standards

Next Generation Science Standards

Structures and Properties of Matter

- PS1.A: The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.

Heat

- PS3.A: The term “heat” as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects.

Common Core English Language Arts Standards

Science & Technical Subjects, Grades 6–8

- RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts.

Speaking & Listening

- SL.2 Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.
- CCRA.SL.4 Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.

Welding Investigation handout, page 1 of 2

Part 1: Welding in our School

Directions: Search for examples of welding throughout the school in each of the categories below. If you are successful, describe *where* you found each example and sketch a picture of what it looks like.

Tip: Metal has likely been welded when different pieces appear to be attached to each other without the help of nails, screws, or glue!

Seats (Chairs, stools, benches, and bleachers all count!)	
Location: Where did you spot this welded item?	Sketch: What does it look like?
Desks & Tables	
Location: Where did you spot this welded item?	Sketch: What does it look like?
Bookcases & Shelves	
Location: Where did you spot this welded item?	Sketch: What does it look like?
Free Category: (Stuck? Think about where you throw out your trash, decorations worn on your body, where food is cooked, and/or how you enter/exit rooms.)	
What did you find and *where* did you find it?	Sketch: What does it look like?

Welding Investigation handout, page 2 of 2

Part 2: Welding in the World

Directions: Use the hints below to fill in the blanks and discover a few other places where welding is used! One __ = One letter!

1. Commercial __ __ __ __ __ __ __ __ __ weigh around 90,000 pounds and travel about 500 miles per hour.

2. Welding is used to construct __ __ __ __ __ __ __ __ __ __ __ and repair them. You likely rely on these vehicles to get around!

3. Most __ __ __ __ __ __ __ can carry more than 6,000 pounds and reach a top speed of about 22,000 miles per hour!

4. The tallest __ __ __ __ __ __ __ __ __ __ in the world is 2,716 feet tall.

5. Crossing over a body of water? Chances are high that you're going to drive over a __ __ __ __ __ __ .

6. Speaking of water: Welding is one of the reasons why __ __ __ __ __ don't sink!

Welding Background

This article contains excerpts from Jonathon Atterbury's "How Welding Works" article published on science.howstuffworks.com/welding.htm. Sections of the original article have been removed and modified and new explanatory text has been added.

Skyscrapers, exotic cars, rocket launches—certain things simply demand your attention. Welding, in all likelihood, isn't one of them. You may have gone your whole life without ever having thought about the subject. It might surprise you then, that welding affects an estimated 50 percent of the United States gross national product. Without it, none of those amazing skyscrapers, cars or rockets would exist.

Welding is, at its core, simply a way of bonding two pieces of metal. While there are other ways to join metal (riveting, brazing and soldering, for instance), welding has become the method of choice for its strength, efficiency and versatility.

With all the power and precision machinery involved in production welding, you might think of welding as a relatively new process. In reality, welding has been around for thousands of years. Early examples of welding have been found in locations ranging from Ireland to India, with some dating back to the Bronze Age. Naturally, these civilizations lacked the vast array of tools and machinery that welders have access to now. How did they manage to weld?

The process they used is known as forge welding. To start the process, blacksmiths would heat the metal until it was bright red in color (but still not at its melting point). The blacksmiths would then place the two pieces, slightly overlapping, on an anvil and pound them together. Forge welding has multiple limitations. Only relatively soft metals can be forge-welded, and the process is very labor intensive. In places without electricity, however, the process is still used.

Most welding done today falls into one of two categories: arc welding and torch welding.

Both types of welding involve melting two metal pieces (which are often called "work pieces"), in addition to a filler metal. A filler metal is a third piece of metal that helps to join the two work pieces by filling any space between them. Both arc welding and torch welding transfer heat energy to the metals. When the work pieces and the filler metal are heated, they melt, join, and fusion occurs. This means that the three pieces of metal have melted together into one—and, once cooled, the resulting bond is even stronger than the original metal.

Arc welding uses an electrical arc (e.g. electricity) to melt metals. In arc welding, a piece of metal called an electrode is connected to a strong power supply. When the electrode is placed near the metals being connected, an electric arc is generated. This arc is a little like the sparks you see when pulling jumper cables off a car battery. The arc then melts the work pieces, as well as the filler material that helps join the two work pieces.

Torch welding uses an oxyacetylene torch (a tool that combines oxygen and gas to create heat hot enough to cut and weld metal) to melt the work pieces and the welding rod. The welding rod is made up of the same type of metal as the metals that are being joined—so when the welding rod melts, the three metals can become one. The welder controls the torch and rod simultaneously, giving him or her a lot of control over the weld. While torch welding has become less common industrially, it's still used for maintenance and repair work, as well as in sculptures.

Once a weld is in place, you can check its quality in several ways. Visual inspection can reveal evidence of welding performed at the wrong speed, cracks in the weld, and other problems. Welders may also inspect their work using magnetic particle testing, liquid penetration inspection, ultrasonic testing, X-ray inspection, pressure testing, or other methods. Destructive testing, which destroys the weld under examination, is also frequently used to determine the quality of a weld. No matter what test is used, ensuring welds are strong and durable is an important step in the process.

Station: *Welding Background* article

Directions:

7. Read the *Welding Background* article twice. The first time you read the article, try to get the gist (or general idea) of the text.
8. Before you read the article a second time, read through the questions below. Then read the article once more and annotate for details that may help you answer these questions.
9. Use your annotations to answer the questions below!

1. In a nutshell, what is welding?

2. What are two main types of welding, and what is unique about each one?

Station: Welding in Space

Directions: Watch the following two videos and then answer the questions that follow.

- NASA Now: tinyurl.com/y2s8wkgf (from 1:35–3:20)
- Welding Wonder: tinyurl.com/y44bclbq (entire video)

1. In a sentence or two, what is friction stir welding?

2. How does welding contribute to innovations, or new developments, in aerospace?

Station: Simulation

Directions: Read and complete each step below. Before you move on to the next step, be sure to discuss the questions provided.

Step 1: With your partner, use the hot glue gun to quickly draw one squiggly line of hot glue on two pieces of carboard. Then, as quickly as you can, press the two pieces together and hold them in place for five seconds.

Discuss:

1. Arc welding and hot glue guns have similar energy transfers. In other words, they both help energy transfer from one form to another in similar ways.

   Think about the hot glue gun that you just used. Then consider: Would you describe the energy transfer that occurs when you use a hot glue gun as electrical-to-thermal energy or chemical-to-thermal energy? Why?

2. Welding and hot glue guns also create the same kind of matter changes. Matter can take the form of solid, liquid, and gas. What changes occurred during the hot glue process?

   Note: In actual welding, it's not just the connecting material that melts… the two metals being joined together melt as well! This makes a welding bond even stronger than a hot glue bond.

Step 2: Next, simulate a couple other ways that metals can attach to one another:

1. **Bolts:**
   Background: Bolts are large screws that, when turned, can fasten one piece of metal to another.
   Simulate: Use the stapler to attach two new pieces of cardboard together by inserting two staples
2. **Soldering:**
   Background: Soldering attaches two materials by using a melted filler material.
   Simulate: Spread liquid glue on one piece of cardboard. Then press this piece to another piece of carboard and hold them together for 5 seconds.

Step 3: Time to test which bond is strongest! Try to pull each of the three bonds apart.

Discuss:

1. Which bond (simulated welding, bolts, or soldering) was the hardest to pull apart?

2. Why do you think welding is important in aerospace?

Career Fair (page1 of 2)

I am a

welding engineer
welding supervisor
robotic welding technician
welding fabricator
welding inspector
welding research scientist
welding technician

Step 1: Read the *Welding Career Navi System* article and annotate for important details related to the education needed for a welding career.

Step 2: Go to careersinwelding.com/careers-in-welding, find the section that mentions your career, and read about it! As you do, record notes in the following categories:

Training Requirements & Suggestions	Job Responsibilities	Other Interesting Facts about This Career
Looking for more information? Search for real job postings at careers.org or find additional background information at study.org.		

Step 3:

In general, aerospace welders work on equipment and technology found in airplanes, space shuttles, rockets, and other similar structures. Now that you know your career's overall responsibilities, what may you be responsible for if you were hired in the aerospace field?

For instance: What role might you play in the construction of a rocket? It's okay to make inferences but base your inferences on your job description. Brainstorm your ideas below:

Career Fair (page1 of 2)

Step 4:
Now pretend you are working in the aerospace industry in your assigned career. You must prepare to share your career with middle school students. Use your research notes to fill in the blanks below, so you are ready to present at the career fair!
Tip: You may be a little creative with your answers, but everything must be based on the research that you completed.

My job is: _____

To prepare for this job, I:
(Discuss the training or education you received)

_____

_____

_____

_____

_____

I am responsible for:

_____

_____

_____

_____

_____

I think my job is important for space exploration because:

_____

_____

_____

_____

_____

Career Fair Notes

As you listen to the career fair presentations, choose two welding careers that most interest you. Record the names of these careers below, as well as at least two important or interesting facts:

Welding Career: _____
Important or Interesting Facts:

Welding Career: _____
Important or Interesting Facts:

Career Fair Notes

As you listen to the career fair presentations, choose two welding careers that most interest you. Record the names of these careers below, as well as at least two important or interesting facts:

Welding Career: _____
Important or Interesting Facts:

Welding Career: _____
Important or Interesting Facts: