Molecular Properties of Welding Materials

Companion Lesson to X-STEM All Access Episode "Welding: It's a STEM Job"

Grade Band: Middle & High School	**Topic:** Physical Science

Brief Lesson Description: Students test metal properties related to welding and use to solve challenges.

Performance Expectation(s):

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.

HS-PS2-6: Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

MS-PS1-3: Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.

MS-PS1-4: Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

Specific Learning Outcomes:

Students will be able to…

1. Explain how molecular properties influence welding.
2. Conduct investigations to determine the suitability of welding materials.
3. Analyze and evaluate the factors that contribute to material selection in welding.
4. Apply engineering principles to design solutions involving welding.
5. Communicate scientific information about design solutions.

Narrative / Background Information

In the lesson, students will explore how the molecular structure of different metals influences their behavior during welding. With the foundational knowledge of atomic structure, bonding, crystal lattices, and heat treatment, students will be better equipped to understand why certain metals perform better in welding processes and how engineers use this information to solve real-world challenges. This background also prepares them to analyze and justify material selection in the design challenges presented during the lesson.

Science & Engineering Practices:	Disciplinary Core Ideas:	Crosscutting Concepts:
Asking Questions and Defining Problems Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (HS-ETS1-1) **Developing and Using Models** Develop a model to predict and/or describe phenomena. (MS-PS1-4) **Obtaining, Evaluating, and Communicating Information** Communicate scientific and technical information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-PS2-6) Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or now supported by evidence. (MS-PS1-3)	**ETS1.A: Defining and Delimiting Engineering Problems** Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-ETS1-1) Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges may also have manifestations in local communities. (HS-ETS1-1) **PS1.A: Structure and Properties of Matter** Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (MS-PS1-3)	**Cause and Effect** Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS1-4) **Structure and Function** Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and the connections of components to reveal their function and/or solve a problem. (HS-PS2-6) Structures can be designed to serve particular functions by taking into account the properties of different materials, and how materials can be shaped and used. (MS-PS1-3) ***Connections to Engineering, Technology, and Applications of Science*** **Influence of Science, Engineering, and Technology on Society and the Natural World** New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs

	Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. (MS-PS1-4) In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. (MS-PS1-4) The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. (MS-PS1-4) **PS1.B: Chemical Reactions** Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-3) **PS2.B: Types of Interactions** Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. (HS-PS2-6) **PS3.A: Definitions of Energy** 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. *(secondary)* (MS-PS1-4) The temperature of a system is proportional to the average internal kinetic energy and potential energy per atom or molecule (whichever is the appropriate building block for the system's material). The details of that relationship depend on the type of atom or molecule and the interactions among the atoms in the material. Temperature is not a direct measure of a system's total thermal energy. The total thermal energy (sometimes called the total internal energy) of a system depends jointly on the temperature, the total number of atoms in the system, and the state of the material. *(secondary)* (MS-PS1-4)	and benefits is a critical aspect of decisions about technology. (HS-ETS1-1) The uses of technologies and any limitation on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time. (MS-PS1-3) **Interdependence of Science, Engineering, and Technology** Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. (MS-PS1-3)

Possible Preconceptions/Misconceptions:
Students bring various preconceptions/misconceptions to this topic. They may include:
1. All metals are the same and do not have a structure at the molecular level.
2. Welding is just gluing two metals together.
3. Welding changes the chemical composition of metals.
4. Heat causes melting which weakens all metals.
5. Strong metals are harder to weld.
6. Welds are as strong as the base metal.

LESSON PLAN – 5-E Model

ENGAGE: Opening Activity – Access Prior Learning / Stimulate Interest / Generate Questions:

Start the lesson by asking students to watch this short video that shows the structural failure on a roller coaster. After watching the video, ask students to consider the following questions and discuss as a class.

1. ***"What might have caused this failure?"***
2. ***"How could a better understanding of materials prevent this failure?"***
3. ***"How might this failure impact humans?"***

Explain to students that this failure was caused by a poor weld. Next, ask students ***"What is welding?"*** and have them share their answers to the group.

Show the X-STEM Video "Welding: It's a STEM Job". After the video, ask students again to explain what welding is. Explain to students that in this lesson they will explore the importance of molecular structure in material science and engineering.

EXPLORE: Lesson Description – Materials Needed / Probing or Clarifying Questions:

Students will perform a hands-on investigation using metal samples to observe how different metals react to heat (simulating the welding process). They can observe melting points, conductivity, and material behavior under stress.

Provide each student with a copy of the Student Handout. Review the materials, safety notes, and directions with students prior to completing the activity.

Teacher facilitation notes:
Encourage students to discuss their findings and compare results.
Facilitate a discussion connecting the observed properties to molecular structures, such as metallic bonding and lattice structures.

After students complete the investigation, discuss the following prompts as a class:
Which metals performed best during the heating process? Why?
How does the molecular structure of these metals affect their properties?

EXPLAIN:

Provide each student with a copy of the Student Text. Have the students read the text and complete the comprehension questions. Then discuss the answers to the comprehension questions to check for student comprehension.

Alternatively, these notes may be used to provide students with direct instruction on the topic.

ELABORATE: Applications and Extensions:

Students will participate in an Engineering Challenge. Students work in teams to design a solution for a welding-related challenge, such as improving the durability of a welded joint in a specific environment (e.g., underwater, high temperature). They must consider the molecular structure of materials and justify their choices based on their properties.

Steps:
1. Provide each group with a Welding Challenge Card, a set of Material Cards, and a Challenge Record Sheet.
2. As a team, define the problem and constraints. Record on the Challenge Record Sheet.
3. Use the Material Cards to research and select materials based on their molecular properties.
4. Create a design proposal, including a justification for material selection. Record on the Challenge Record Sheet.
5. Present the solution to the class.

Class Discussion Questions after Presentations:
- ***How did your understanding of molecular properties influence your design?***
- ***What were the trade-offs in selecting materials for your solution?***

EVALUATE:

Formative Monitoring (Questioning / Discussion):
Prompts throughout the lesson in ***bold and italics*** and posters of graph two analysis can be used to check student understanding throughout the lesson.

Summative Assessment (Quiz / Project / Report):
Provide students a copy of the Quiz. Use the provided rubric and example answer key to assess student understanding.

Elaborate Further / Reflect: Enrichment:
Students can extend their learning by conducting research on different welding techniques (e.g., MIG, TIG, stick welding) and creating a presentation comparing their advantages, disadvantages, and ideal applications.

CAREER CONNECTIONS

There are a wide variety of careers students can pursue in the Metallurgy and Welding Industries. From erecting cranes/derricks as a pipefitter to underwater welders, there are many interesting careers for students to learn about. The following activity will provide students an opportunity to learn about these careers.

Go to https://usasciencefestival.org/resources/ to access the Student Career Resources.

Select the Metallurgy and Welding Industry.

Have students browse the careers within your chosen cluster. Select one career that they would like to learn more about. They should then gather the following information using the student graphic organizer or in a class notebook:

- Job description and typical responsibilities
- Education and training required
- Skills and qualities needed
- Average salary
- Work environment and schedule
- Professional Organizations, Educational Programs, and Internship & ApprenticeOpportunities

Choose a Choice Board Activity and use the information gathered to complete the chosen activity.

Career Slogan Develop a catchy slogan or tagline that promotes the importance or appeal of your chosen career.	**Career Trivia** Develop a trivia game with at least 10 questions about your chosen career, including facts about the industry, education, and skills.	**Career Comic Strip** Design a comic strip depicting a significant moment or challenge someone in this career might face.

Provide students an opportunity to share their findings with peers or with you.

SOCIAL EMOTIONAL LEARNING ACTIVITY

CASEL Competency Addressed: Self Awareness

In the X-STEM Episode “Welding: It’s a STEM Job”, Shanen Aranmor talks about the importance of trying new things. This lesson will focus on the concept of trying new things and its relevance in both personal growth and academic experiences.

Start with a short personal story about trying something new (e.g., a teacher trying a new hobby or sport). Discuss the initial fears or doubts and the eventual outcomes. Then discuss the following questions in small groups**:**

- ***Have you ever tried something new? What was it like?***
- ***How did you feel before you tried it, and how did you feel afterward?***

Next, have students reflect on their feelings and attitudes towards trying new things. Questions might include:

- ***What are some new activities or experiences you have wanted to try?***
- ***What fears or concerns do you have about trying something new?***
- ***How do you usually respond to new challenges or experiences?***

Discussion and Role-Playing: Discuss common fears about trying new things (e.g., fear of failure, embarrassment) and strategies to overcome them (e.g., positive self-talk, setting small goals).

Role-play scenarios where students might face these fears and practice using the strategies discussed. Divide students into groups and provide them with a role-play scenario. Give them time to try the scenario and then discuss:

- ***What strategies can help you overcome fear when trying something new?***
- ***How can setting small goals make trying new things easier?***

INTERDISCIPLINARY CONNECTIONS/IDEAS

Mathematics: Use lessons from the NSF Math Curriculum for Welders to have students explore the relationship between welding and math. Topics include whole numbers, fractions, decimals, measurement, integers, algebra, geometry, and trigonometry.

Art: Use the Iroquois Lesson plan for students to consider a welded public art project and the role of teamwork.

Career and Technical Education: Have students research the variety of welding careers and create an infographic to describe professions that use welding. Possible careers to research include Structural Iron and Steel Welders, Oil Rig Welders, Pipe Welders, Welding Engineers, Boilermaker, Motorsports Fabricators, Sheet Metal Workers, MIG Welder, Master Jeweler, Master Plumber, and Welding Inspectors.

Materials Required for This Lesson/Activity

Quantity	Description
1 Per Group	Metal Samples including: -Iron -Copper -Aluminum -Stainless Steel -Brass
1 Per Group	Bunsen Burner or Heat Source
1 Per Group	Crucible Tongs
1 Per Group	Thermometer Capable of Measuring High Temperatures or Temperature Probe
1 Per student	Safety Goggles
1 Per Group	Metal File

X STEM ALL ACCESS | A PROGRAM OF USA SCIENCE & ENGINEERING FESTIVAL

Lesson Created by Jess Noffsinger
For questions please contact
info@usasciencefestival.org