Evaluating Engineering Materials

Companion Lesson to X-STEM All Access Episode "It's A Material World"

Grade/ Grade Band: High School	**Topic:** Engineering

Brief Lesson Description: Students will synthesize copper, compare its properties to bronze and use this data to evaluate engineering materials for different applications.

Performance Expectation(s):
NGSS-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.

Specific Learning Outcomes:
-Students will define material and identify materials in their daily lives.
-Students will follow a procedure to synthesize a metal (copper) and observe its structure over time.
-Students will use technical information to determine the properties of materials.
-Students will define the needs for engineering materials and use them to determine which material best meets the needs.
-Students will justify the material choice using specific evidence.

Narrative / Background Information

Prior Student Knowledge:
-Students know that different materials can be identified based upon characteristic properties.
-Students can follow a simple procedure to conduct an experiment.

Science & Engineering Practices:	**Disciplinary Core Ideas:**	**Crosscutting Concepts:**
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade off considerations. **(HS-ETS1-3)**	**ETS1.B: Developing Possible Solutions** When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts. **(HS-ETS1-3)**	**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 and benefits is a critical aspect of decisions about technology. **(HS-ETS1-3)**

Possible Preconceptions/Misconceptions:
-Properties of materials are different based on the sample rather than inherent attributes of the material.
-The properties of an alloy must be "weaker" than the pure metals that are combined to make them.

LESSON PLAN – 5-E Model

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

Start the class by having students answer the following three prompts:

1. *Define the word material in your own words.*
2. *Make a list of different materials you have used today.*
3. *How would your life be different if everything was made out of one material such as wood?*

Discuss answers to the prompts as a class and then introduce students to the field of materials science and engineering.

"Materials Science and Engineering is an exciting STEM field that we are going to explore in this lesson. Materials Scientists study the properties, processing and application of thousands of different materials. It includes many subfields including metallurgy, polymer science, additive manufacturing (3D Printing) and many more. To learn about this exciting field, we are going to watch an X-STEM video featuring Dr. Angela Moran."

Show the XSTEM Episode "It's a Material World". After the video, have students discuss what they noticed and wondered during the video.

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

Explain to students that Materials Engineers study four main classification of materials: Metals, Ceramics, Polymers, and Composites. This lesson will focus on studying metals and the alloys that they are used to create.

Students will begin by exploring a common metal–Copper. Ask students to generate a list of what they know about copper including its properties and uses. Record their list on the board.

Next, explain to students that they will be synthesizing copper today using the directions in the **lab handout.** Students should follow directions and conduct the reaction. They will make observations over the next few class periods to provide their copper crystals time to group.

On the second day of this lesson, start by having students make observations about copper. Compare them to the list generated yesterday. Typically, the main difference students will observe is that copper forms as a crystal rather than as wires or pipes. This leads into the Explain section of this lesson.

Observations on a third day (or longer) allow for crystals to fully develop. This takes limited class time, but allows students to see crystal formation. At the end of the activity, students may take the copper that they formed if you would like. They need to slowly pour the preform into a plastic cup or beaker. Next, carefully separate the copper from the other solids using a spoon or other probe. Remove the copper from the cup using the spoon. Then, gently rinse the copper with water using an eyedropper or disposable pipette. Place copper on a paper towel to dry. (Note–it typically is best to send home copper only when students all have their own tube.)

Teacher Notes on Activity:
-Review safety precautions with students prior to handing out materials.
-Preforms can be purchased on Amazon or most major science suppliers.
-The cotton used in the experiment can be either makeup removing pads or cotton balls. Both should be well soaked and sized to fit the tubes that are being used so that they are not too thick. (Cutting the pads in smaller pieces or larger cotton balls in half may be needed.)
-Air pockets sometimes form in the test tube. Inserting and then removing a thin copper wire down the inside of the test tube will often release the trapped air.
-Additional information about this activity can be found in NSTA The Science Teacher "Grow Your Own Copper Deposit" December 2009.

EXPLAIN:

Ask students *"Why do you think engineers must understand the properties of materials like copper before they use them in designs or design new materials using them?"* **Discuss responses as a class.**

Introduce students to the term Alloy by showing the video "What is an Alloy?" After the video, ask students to explain to a partner what an alloy is in their own words.

Next, ask students *"What are some alloys that you think you know of or use in your own lives?"* Have students generate a list. Then show the video "Alloys: Types and Examples".

Explain to students that their next task is to determine how an alloy changes its properties from a pure metal. They will do this by comparing copper (like they synthesized) and bronze, a common alloy of copper.

Hand out Graphic Organizer to each student. Pair students with a partner. Hand out one of the Task Cards to each set of partners. Provide students 3-5 minutes per task card to read the information and complete the graphic organizer. Have students pass their task card to the next group and continue to rotate until all groups have had all cards.

After completing the organizer, have partners discuss the following questions together:

1. *How are alloys (like bronze) different from their original base material (copper)?*
2. *Based on the video, why do you think these differences occur?*

Then discuss ideas as a class.

ELABORATE: Applications and Extensions:
Explain that materials engineers evaluate the properties of metals and alloys to determine the best material for different applications. When they are doing these evaluations, they must consider many different factors and trade offs. Tell students that they will take on the role of engineer to determine what material should be used for different engineering applications.

Provide each student with a copy of the Copper versus Bronze Scenarios. Explain to students that each scenario discusses the needs or factors that are to be considered. Remind them that they may use their graphic organizer as supporting evidence to make their decisions.

After students have had time to complete the scenarios, have a class discussion about each scenario.

EVALUATE:

Formative Monitoring (Questioning / Discussion):
Use Questions throughout the lesson (found in *italics)* to check student understanding and progress throughout the lesson. You should also review the Copper versus Bronze Scenarios to determine if students are ready to take the summative assessment.

Summative Assessment (Quiz / Project / Report):
Students can demonstrate their mastery of this lesson by taking this written **Assessment.** There is a rubric at the end of the assessment to determine student proficiency.

Elaborate Further / Reflect: Enrichment:
Students may expand their understanding of materials engineering by completing a variety of lessons found in the ASM Camp Work Book Activities. Lessons focus on solids, metals, polymers, composites, and ceramics and are classroom tested for you to use successfully.

SOCIAL EMOTIONAL LEARNING ACTIVITY

In the X-STEM Video "It's a Material World," Dr. Moran describes the importance of networking as a skill to build a career. Today students will explore the idea of networking and practice giving an elevator pitch to market themselves.

Start by having students define what the word networking means in terms of building career connections. After students have shared their idea, show the video "What is Networking Anyway?" Following the video, ask students what they would add to their definitions after listening to the video.

Next, have students work with a partner. Tell them that they have 30 seconds in an elevator to sell themselves to someone they meet from a local company. Set a timer and have student 1 give a quick pitch to the other. Stop at exactly 30 seconds. Then have students switch roles.

As a class, discuss the following prompts:

1) How did it feel to sell yourself?
2) What did your partner do to impress you? to annoy you?
3) Did your partner convince you to hire them? Why or why not?

Next, show students the video "30 Second Elevator Pitch". Have students spend time creating a 30 second pitch based on the recommendations in the video. Then, have them practice their pitch with a partner.

Again, have students discuss the prompts above.

Talk about opportunities students might have to network in their current lives. Emphasize the importance of having a well thought out pitch and keeping it current in finding a job.

INTERDISCIPLINARY CONNECTIONS/IDEAS

Chemistry: Students studying metallic bonds and crystal structures can use these properties to classify a variety of materials using this lesson from Boise State University.

History: Students can use the lesson " Fighting Corrosion to Save Ancient Greek Bronze" to discover how antiquities are preserved using materials engineering.

ELA: Students can practice their listening and summary skills while listening to "The Materials Universe'' podcast. This Narrative Non-Fiction resource explores how materials impact our daily lives. Students can analyze the podcast, write summaries, and/or develop additional episodes based on a material that they research.

Materials Required for This Lesson/Activity

Quantity	Description
1 per student	Soda Bottle Preform or test tube with stopper
2 per student	Bright Iron Nail (2-3 inches in length)
~10 g per student	Copper (II) Sulfate Pentahydrate (Medium Crystals)
1 per student	Plastic Cup
1 Container	Non-Iodized Salt
1 per 6 students	Preform or test tube rack
1 per student	Cotton Makeup Removal Pad or Large Cotton Ball
1 box	Steel Wool
50 mL per student	Water

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