Corrosion and Materials in Underwater Robots

Companion Lesson to X-STEM All Access Episode "Autonomy Under Water"

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

Brief Lesson Description: Students investigate the effects of corrosion on different materials and apply to real world problems.

Performance Expectation(s):

HS-ETS1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS-PS1-5: Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs. [Clarification Statement: Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.] [*Assessment Boundary: Assessment is limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.*]

MS-PS1-2: Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred. [Clarification Statement: Examples of reactions could include burning sugar or steel wool, fat reacting with sodium hydroxide, and mixing zinc with hydrogen chloride.][*Assessment boundary: Assessment is limited to analysis of the following properties: density, melting point, boiling point, solubility, flammability, and odor.*]

Specific Learning Outcomes:

1. Students will explain the chemical processes behind corrosion, including oxidation-reduction reactions, and identify factors that accelerate corrosion in underwater environments.
2. Students will analyze and compare the properties of different materials used in underwater robotics, including their resistance to corrosion, strength, and suitability for specific applications.
3. Students will apply scientific principles related to reaction rates and material science to design an underwater robot that minimizes corrosion and performs effectively in a marine environment.
4. Students will design and prototype an underwater robot, considering material choices, durability, and performance in various underwater conditions.
5. Students will evaluate their designs and those of their peers, providing constructive feedback and reflecting on how their understanding of corrosion and material science influenced their engineering solutions.

Narrative / Background Information

Students should have the following background prior to this lesson:
-Chemical reactions occur when a new form of matter is produced. These reactions are affected by a variety of factors including temperature and concentration.
-Different materials have different properties that are used to determine their uses.
-Metals corrode when exposed to salt water.
-A basic understanding of the engineering design process including problem identification, solution brainstorming, and prototyping.
-Awareness of how environmental factors such as salinity, temperature, and pH can impact materials and their performance in real-world settings, especially in aquatic environments.

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. • Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade off considerations.	**ETS1.C: Optimizing the Design Solution** Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2) **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-PS1-2) **PS1.B: Chemical Reactions** Chemical processes, their rates, and whether or not energy is stored or released can be	**Patterns** Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS1-5) Macroscopic patterns are related to the nature of microscopic and atomic-level structure. (MS-PS1-2)

(HS-ETS1-2) • Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. (HS-PS1-5) **Analyzing and Interpreting Data** Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. • Analyze and interpret data to determine similarities and differences in findings. (MS-PS1-2) ***Connections to Nature of Science*** **Scientific Knowledge is Based on Empirical Evidence** • Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS1-2)	understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. (HS-PS1-5) 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-PS1-2)	

Possible Preconceptions/Misconceptions:

1. **Misconception:** Students might believe corrosion is only about rust on iron and that it's a simple, one-dimensional process. **Clarification:** Corrosion is a broader phenomenon affecting various metals and materials, not just iron, and involves complex chemical reactions that can vary based on environmental conditions.
2. **Misconception:** Students might think all metals corrode at the same rate and in the same way. **Clarification:** Different metals and alloys corrode at different rates depending on their properties and the specific environmental conditions, such as salinity and pH.
3. **Misconception:** Students might assume that simply choosing a corrosion-resistant material is enough to solve corrosion problems in underwater robots. **Clarification:** Effective corrosion management involves a combination of material choice, design considerations, protective coatings, and environmental factors.
4. **Misconception:** Students might think that chemical reactions, including those causing corrosion, always occur quickly and are immediately visible. **Clarification:** Corrosion and other chemical reactions can be slow processes, and their effects may not be immediately visible, requiring careful observation and measurement over time.
5. **Misconception:** Students might assume that underwater robots are similar to land-based robots and that the same materials and designs are equally effective in both environments. **Clarification:** Underwater robots face unique challenges such as pressure, salinity, and temperature, which require specific materials and design adaptations to ensure performance and longevity.

LESSON PLAN – 5-E Model

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

Show students the X-STEM All Access Video "Autonomy Under Water" featuring Amy Kukulya. After watching the video, discuss the following questions:

1. ***Ask students to brainstorm potential challenges these robots might face in underwater environments, specifically focusing on material degradation.***
2. ***What do they think happens to metals underwater?***
3. ***How might this impact the robot's function over time?***

After discussing, introduce the focus question for the remainder of the lesson:
"How does the underwater environment affect the materials used in constructing underwater robots?"

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

Students will complete two hands-on activities to understand corrosion reactions.

Activity 1: Corrosion Experiment
Materials: Each group of students will need the following materials: different types of metals (e.g., iron, aluminum, copper), saltwater, beakers, sandpaper, and pH strips.
Procedure: Students will sand small pieces of each metal to remove any protective coating, place them in saltwater, and observe the changes over a few days. They will use pH strips to measure the acidity of the water before and after the experiment.
Data Collection: Students will record observations daily, noting any visible corrosion, changes in pH, and comparing the rate of corrosion between metals.

Optional Temperature Sensor Extension with Pocket Lab Voyager:
Setup: In addition to the saltwater beakers, set up a controlled environment where the temperature of the saltwater can be varied (e.g., one beaker at room temperature, another in a heated environment (such as under a heat lab), and another in a cooled environment (such as a cooler with ice))
Temperature Monitoring: Use the temperature sensor to monitor and record the temperature of each beaker throughout the experiment. Ensure the temperature is consistent and stable in each environment.
Data Collection: Students will observe and record not only the visible signs of corrosion but also how temperature impacts the rate of corrosion. They will measure the temperature with the sensor and correlate it with the pH changes and visible corrosion over time.
Analysis: Students will analyze the data to determine if higher or lower temperatures accelerate or slow down the corrosion process. They can compare the corrosion rates across different temperature settings to draw conclusions about the relationship between temperature and corrosion.

Activity 2: Material Science Investigation
Materials: Various materials used in underwater robots (e.g., stainless steel, plastic, composite materials,etc).
Procedure: Students will research the properties of these materials, such as tensile strength, resistance to corrosion, and buoyancy.
Analysis: They will compare the advantages and disadvantages of each material in the context of underwater robotics.

After completing the two activities, discuss the following questions as a class:

1. ***What materials are most resistant to corrosion, and why?***
2. ***How do the properties of different materials affect their performance in underwater robots?***

EXPLAIN:

For students to learn about the chemistry of corrosion, have them complete this EdPuzzle Video "Rust and Corrosion".

You may want to follow up with a mini lecture that explains the chemical reactions that lead to corrosion, focusing on oxidation-reduction reactions (high school). Discuss the factors that accelerate corrosion, such as salinity, temperature, and pH.

Next, relate the experimental findings from the Explore phase to the concepts discussed in the lecture. ***Why did certain metals corrode faster than others? How does the underwater environment contribute to these reactions? How can we apply our understanding of corrosion and material properties to improve the design of underwater robots?***

ELABORATE: Applications and Extensions:

Students will work in small groups to design an underwater robot. Provide each student a copy of the Designing an Underwater Robot Handout. Review the objective of the challenge and the instructions for creating an annotated sketch. Have students review the checklist of what is expected on a completed design.

It may be helpful to provide students examples of an annotated sketch. Here are three examples: Example 1, Example 2, Example 3

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):
Presentation: Each group will present their underwater robot design to the class, explaining the materials chosen, the expected performance in underwater environments, and how their design addresses the problem of corrosion.

Peer Review: After presentations, students will provide feedback on each other's designs, focusing on the strengths and weaknesses of the material choices and overall design.

Rubric: Rubric to assess student designs following the presentations is provided.

Elaborate Further / Reflect: Enrichment:
Advanced Research: Students can explore advanced materials like alloys or coatings that resist corrosion or investigate real-world underwater robotics projects and the materials used.

Field Trip/Virtual Tour: Arrange a visit to a local marine engineering facility or a virtual tour to see how professionals deal with corrosion in marine environments.

CAREER CONNECTIONS

There are a wide variety of careers students can pursue in the Robotics and Materials Engineering Industries. From Autonomous Vehicle Engineers who design the robots in this episode to Materials Scientists who study how different materials corrode, 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 Robotics and/or Material Science Industries.

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.

Resume for the Future Create a resume as if you are applying for a job in your chosen career 10 years from now. Include education, experience, and skills.	**Work Environment Design** Draw or digitally create an image of the typical work environment for this career. Annotate it with labels explaining the features.	**Career Advertisement** Create a commercial (video or audio) to promote your chosen career to others. Highlight its benefits and opportunities

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

SOCIAL EMOTIONAL LEARNING ACTIVITY

CASEL Competency: Self Awareness

In "**Autonomy Under Water**", Amy Kukulya talked about the importance of having a personal mantra that helps to motivate you in a variety of ways. This lesson will focus on students creating their own personal mantras.

Start the lesson by asking students "Has there ever been a phrase or quote that motivates you or makes you feel better when you're down?" Allow a few students to share their responses.

Next, write the word **"Mantra"** on the board. A mantra is a word or phrase that is repeated often to motivate and encourage oneself. It can help focus the mind, boost confidence, and remind us of our inner strengths and values. Provide a few examples such as "I can do hard things" or "Nothing lasts forever. Not the good, not the bad."

Highlight how having a personal mantra can:

- Increase self-awareness and understanding of personal values.
- Provide encouragement during challenging times.
- Help manage stress and emotions.
- Reinforce positive self-identity.

Provide students with the "Personal Mantra Worksheet." Have them complete the steps to create a personal mantra.

After each student completes the activity, discuss ways students can use their mantras regularly:

- Repeat it in the morning to start the day positively.
- Use it during stressful or challenging situations.
- Write it somewhere visible (e.g., on a notebook, locker, or bedroom wall).

Ask students to close their eyes and silently repeat their mantra a few times, noticing any changes in their feelings or thoughts.

End with a positive affirmation, thanking students for their participation and encouraging them to continue using their mantras for self-support.

INTERDISCIPLINARY CONNECTIONS/IDEAS

ELA: Technical Writing

1. Introduce the structure and style of technical reports, including sections like the introduction, methodology, results, and discussion.
2. Assign students to research different materials used in underwater robotics, specifically focusing on their properties related to corrosion resistance.

Visual Arts: Product Design and Industrial Aesthetics

1. Discuss the role of design in engineering, focusing on how aesthetics and functionality must be balanced in product design.
2. Have students create design sketches or 3D models of an underwater robot, paying attention to materials and surface treatments that prevent corrosion.

Mathematics: Quantitative Analysis and Material Durability

1. Introduce the basic principles of corrosion rate calculation, including relevant formulas and units of measurement (e.g., thickness loss per year).
2. Provide students with data on different materials exposed to underwater conditions (e.g., saltwater, freshwater, varying pH levels). Students will calculate the expected corrosion rates using the provided data.

Materials Required for This Lesson/Activity

Quantity	Description
1 per group	Different types of metals (e.g., iron, aluminum, copper)
1 gallon per class	Saltwater
1 per group	1 Beaker for each metal provided
1 per group	Sand Paper
1 per group per metal sample	pH Strips
1 per group	Temperature Sensor (for optional sensor activity) such as Pocket Lab Voyager
1 per group	Various materials used in underwater robots (e.g., stainless steel, plastic, composite materials,etc)

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