Engineering Stronger, Smarter Materials

Companion Lesson to X-STEM All Access Episode "Supercharging Materials Discovery"

Grade Band: Middle School/High School	**Topic:** Materials Science and Engineering

Brief Lesson Description:
Students explore how structure impacts material properties through data analysis and design using composite materials.

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

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

Specific Learning Outcomes:
Students will compare composites and traditional materials using data on strength, flexibility, and cost.
Students will interpret material science datasets to identify trends and justify material choices.
Students will create an elevator pitch about how molecular properties affect material performance and societal impact.

Narrative / Background Information

Modern engineering relies on advanced materials that balance strength, flexibility, and cost-effectiveness. Composite materials, which combine multiple substances to enhance performance, are used in everything from aerospace to sports equipment. Understanding how their molecular structure impacts functionality helps students see the connection between science, technology, and real-world applications. This lesson empowers students to analyze data, think critically about material choices, and communicate their findings—skills essential for future engineers, scientists, and informed consumers. By exploring composites through hands-on investigation and informatics, students gain a deeper appreciation for how materials shape innovation and impact society.

Students should have a basic understanding of different material types (metals, plastics, ceramics, and composites) and their general properties, such as strength, flexibility, and density. Familiarity with data interpretation, including reading graphs and identifying trends, will help them analyze material performance effectively.

Science & Engineering Practices:	**Disciplinary Core Ideas:**	**Crosscutting Concepts:**
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 method used, and describe how they are supported or not supported by evidence. (MS-PS1-3)	**PS1.A: Structure and Properties of Matter** The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (Secondary to HS-PS2-6) 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) **PS1.B: Chemical Reactions** Substances react in chemically characteristic ways. In a chemical process, the atoms that make up the original substance 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)	**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 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 properties of different materials, and how materials can be shaped and used. (MS-PS1-3)

Possible Preconceptions/Misconceptions:

1. **Composite materials are always stronger than individual materials.** While composites can often have superior strength-to-weight ratios, their strength depends on the correct combination of materials, the method of construction, and the application.
2. **Composites are all plastics-based materials.** However, composites can be made from various materials, including metals, ceramics, and carbon fibers, each offering different properties for specific uses.
3. **Informatics is the same as coding.** However, this field also involves analyzing data, designing systems, and ensuring data privacy.
4. **All data is the same.** This misconception overlooks the complexity of data processing, or underestimates the importance of security in handling sensitive information.

LESSON PLAN – 5-E Model

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

Engage students with the world of Materials Science by showing the XSTEM Episode "Supercharging Materials Discovery" with Dr. Taylor Sparks. After watching the video, discuss the following questions as a class:

- ***What is the field of Materials Science? How does it apply to your life?***
- ***What is informatics? How might it help material scientists?***

Next, introduce the phenomenon for this lesson by explaining to students that they will be considering composite materials like the bike frame from the X-STEM video. Next, show the first 2:06 minutes of the video "Carbon vs Aluminum Frames". Ask students to discuss the following question with a partner then as a class:

- ***Why are these materials used instead of traditional materials like metal or wood?***

Establish the focus question for the remainder of the lesson "***How does the molecular-level structure of composite materials contribute to their properties, and how can we analyze this data scientifically?"***

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

Activity 1: Investigating Composite Materials
Divide students into small groups (3-4 students). Provide each group of students with a sampling of composite materials that they can explore. If hands-on materials are not available, provide pictures of materials with common properties.

Have students examine the materials under magnification (if available) and record observations about texture, weight, and flexibility of each material.

After providing time for hands-on exploration, ask students to discuss the following prompts:

- ***What patterns do you notice when comparing the textures, weights, and flexibility of different composite materials? How might these properties relate to their real-world applications?***
- ***How do composite materials differ from traditional materials like metal or wood? What advantages or disadvantages do you think they offer?***

Activity 2: Composite Informatics
Provide students with the "Material Science Informatics Data Set". Ask them to work in small groups to analyze the data using methods appropriate to your students' experience/skill set. Possible strategies could include comparing maximum/minimum values, creating scatter plots, using simple spreadsheets, etc.

After students have completed their analysis, ***discuss as a class.***

EXPLAIN:

Show the students the video "What is a composite material?" After the video, reinforce that properties of the original materials are different based on their design.

Break students into five groups. Provide each group with a different "Composite Material Case Study". Each group should read their case study and discuss the discussion questions. They should then present their findings to their classmates so that all students have access to the five different real-world applications of Composite Materials.

After presentations, help students to synthesize their learning to understand that by combining multiple materials, composites are able to better meet the needs of engineers in a variety of fields.

ELABORATE: Applications and Extensions:

Provide students with the following application scenario:

An automotive company wants to design a new electric vehicle (EV) that maximizes energy efficiency. Traditional steel frames are strong but heavy, reducing the car's range per charge. Engineers are considering composite materials to reduce weight without compromising safety.

Task:
Compare the **strength-to-weight ratio, cost, and environmental impact** of steel, aluminum, and composite materials (e.g., carbon fiber-reinforced plastic). Choose the best material for the car frame and explain how it improves efficiency while maintaining safety.

Have students work in small groups (2-4 students) to create an elevator pitch summarizing their recommendation, including material properties and societal impact.

Have groups present their findings and provide feedback to each other.

EVALUATE:

Formative Monitoring (Questioning / Discussion):
Bold, italic prompts throughout the lesson can be used to check student understanding. You may also review student responses to the data analysis in the Explain section, case studies in the Explain section, and presentations in the Elaborate section.

Summative Assessment (Quiz / Project / Report): Have students respond to the focus question "How does the mole*cular structure of composite materials influence their use in society?"* as an exit ticket. Assess using the iRubric Science Constructed Response Rubric to score student responses.

EXTEND:

Option 1: Provide students an opportunity to develop their own composite material using the "Battle of the Beams" activity from Teach Engineering. Students will use Laffy Taffy and a variety of reinforcements to develop beams with the highest strength.

Option 2: Allow students to research the wide variety of composite materials within a given field such as aerospace, sports, automobiles, construction, etc and create an infographic teaching about the materials' properties and potential future uses.

CAREER CONNECTIONS

There is a wide variety of careers students can pursue in the Materials Science Field. From Metallurgists who develop metal alloys to Materials Engineers designing the lightest composites, 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 Materials Science 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.

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 Addressed: Self-Regulation and Self-Awareness

1. Opening Activity – The Power of Mistakes

Discussion Prompt:

- Ask students: *Have you ever made a mistake that turned out to be a good thing?*
- Share a quick example (e.g., Post-it Notes, penicillin, or chocolate chip cookies—accidental inventions). Remind students that in the X-STEM video, Dr. Sparks said many discoveries in Materials Science were serendipitous!
- Explain that today, they will explore how mistakes and failures can lead to unexpected success.

2. Case Study: The Invention of Silly Putty

Show the video "How Silly Putty went from an industrial accident to a billion-dollar toy." Then discuss the following:

- ***What mistake did James Wright make?***
- ***How did he and others turn this "failure" into something valuable?***
- ***How does this connect to engineering and material science?***

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3. Reflection and Growth Mindset Hands-On Challenge:

- Give each group a small engineering or design challenge (e.g., building a structure with paper and tape that holds weight).
- Tell them they only have 5 minutes to test their idea and then reflect on any mistakes they made.
- After testing, ask: ***What went wrong? How can you improve it?***
- Discuss how failure is part of the learning process.

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4. Closing Reflection

- Have students write or share verbally: ***Describe a time when a mistake helped you learn something new. How can this mindset help in engineering and science?***
- Reinforce the idea that mistakes are stepping stones to success, just like in material science and engineering!

Materials Required for This Lesson/Activity	
Quantity	**Description**
1 Sample per group	A variety of composite materials. Possibilities include: -Plywood -Particle Board (MDF) -Fiberglass -Carbon Fiber sheets -Concrete -Corrugated Cardboard -Foam Core Board -Plaster of Paris with fiber reinforcement -Paper Mache -Duct Tape Layers -Epoxy with Fillers -Resin Coated Paper or Fabric -Rubberized Fabrics -Clay-Polymer Blends
1 Per Group	Magnifying Glass or Stereoscope
1 Per Group	Scale or Electronic Balance

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