Materials Science – Living in a Material World

Curricular Objectives

Students completing this curriculum will understand that:

- The course of human civilization often hinged on developments in materials science.
- Technology and engineering require an understanding of quantifiable material properties.
- Material properties are determined by chemical composition and small-scale structure.
- Unknown materials may often be identified by testing their material properties.

Students will arrive at these understandings through a process on hands-on scientific inquiry. In the process, students will gain valuable experience with the process skills identified in the Common Core math standards as well as the Next Generation Science Standards.

Logistics

Students: 30 students in grades 6 – 8

Location: Activities are suitable for standard classrooms if laptop carts are available. Otherwise frequent visits to a computer lab will be required.

Time: This curriculum is designed for 32 content hours. Times for individual activities are typically 1 to 2 hours and detailed estimates are found at the beginning of each activity.

Background Information

Materials science is an interdisciplinary field concerned with the understanding and application of the properties of matter. Materials scientists study the connections between the underlying structure of material, its properties, its processing methods, and its performance in applications.

Scholars have long classified eras of ancient civilizations by their progress in materials science, coining such terms the Stone Age, Bronze Age and Iron Age. What is known about ancient cultures, especially those without written records, often comes from a scientific examination of the artifacts they left behind. Advances in materials science often went hand-in-hand with other cultural developments. In many cases it was the development of new materials that enabled advances in other realms of human accomplishment. When neighboring nations and cultures came into conflict, whether economic or military, dominance was often achieved by employing more advanced materials.

Although its importance goes back to antiquity, the concept of material science, as a discipline of study, is rather new. Educational programs at the college level now abound and career opportunities in this field are very rewarding for those with the passion and ability to pursue them.

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National Standards

Next Generation Science Standards:

MS-ESS3-3*: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment*

MS-ETS1-1: *Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions*

MS-ETS1-2: *Evaluate competing design solutions using a systemic process to determine how well they meet the criteria and constraints of the problem.*

MS-ETS1-3: *Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success*

MS-PS1-1: *Develop models to describe the atomic composition of simple molecules and extended structures*

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*

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*

MS-PS1-5: *Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved*

MS-PS2-5: *Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact*

MS-PS4-2: *Develop and use a model to describe how waves are reflected, absorbed, or transmitted through various materials*

MS-LS1-1: *Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells*

MS-LS1-3: *Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.*

MS-LS1-5: *Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms*

NGSS Science and Engineering Practices:

SEP1: *Asking questions and defining problems*

SEP2: *Developing and using models*

SEP3: *Planning and carrying out investigations*

SEP4: *Analyzing and interpreting data*

SEP5: *Using mathematics and computational thinking*
SEP6: *Constructing explanations and designing solutions*
SEP7: *Engaging in argument from evidence*
SEP8: *Obtaining, evaluating, and communicating information*

Next Generation Science Standards Reference:
NGSS Lead States. 2013. *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press.

Mathematics Common Core Standards
CCSS.Math.Content.5.OA.B *Analyze patterns and relationships*
CCSS.Math.Content.6.EE.A *Apply and extend previous understandings of arithmetic to algebraic expressions*
CCSS.Math.Content.6.EE.A.2 *Write, read, and evaluate expressions in which letters stand for numbers*
CCSS.Math.Content.6.EE.B *Reason about and solve one-variable equations and inequalities*
CCSS.Math.Content.6.NS.C.8 *Solve real world and mathematical problems by graphing points in all four quadrants of the coordinate plane*
CCSS.Math.Content.6.RP.A *Understand ratio concepts and use ratio reasoning to solve problems*
CCSS.Math.Content.6.SP.B *Summarize and Describe Distributions*
CCSS.Math.Content.7.G.A.1 *Solve problems involving scale drawings of geometric figures, including computing actual lengths and areas from a scale drawing and reproducing a scale drawing at a different scale.*
CCSS.Math.Content.7.EE.B *Solve real-life and mathematical problems using numerical and algebraic expressions and equations*
CCSS.Math.Content.7.NS.A.3 *Solve real-world and mathematical problems involving the four operations with rational numbers*
CCSS.Math.Content.7.G.B *Solve real-life and mathematical problems involving angle measure, area, surface area, and volume*
CCSS.Math.Content.7.RP.A *Analyze proportional relationships and use them to solve real-world and mathematical problems*
CCSS.Math.Content.7.RP.A.2 *Recognize and represent proportional relationships between quantities*
CCSS.Math.Content.HSN.Q.A.1 *Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays*

Mathematical Practices:
CCSS.Math.Practice.MP1: *Make sense of problems and persevere in solving them*
CCSS.Math.Practice.MP2: *Reason abstractly and quantitatively*

CCSS.Math.Practice.MP3: *Construct viable arguments and critique the reasoning of others*
CCSS.Math.Practice.MP4: *Model with mathematics*
CCSS.Math.Practice.MP5: *Use appropriate tools strategically*
CCSS.Math.Practice.MP6: *Attend to precision*
CCSS.Math.Practice.MP7: *Look for and make use of structure*
CCSS.Math.Practice.MP8: *Look for and express regularity in repeated reasoning*

Common Core English Language Arts (ELA) Standards

6-8.RH.7: *Integrate visual information (e.g., in charts, graphs, photographs, videos, or maps) with other information in print and digital texts*
6-8.SL.1: *Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on middle school topics, texts, and issues, building on others' ideas and expressing their own clearly.*
6-8.SL.4: *Present claims and finding, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details*
SL.6-8.6: *Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate*
6-8.RST.1: *Cite specific textural evidence to support analysis of primary and secondary sources; connecting insights gained from specific details to an understanding of the text as a whole*
6-8.RST.2*: Determine the central ideas or information of a primary or secondary source; provide an accurate summary*
6-8.RST.3: *Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks*
6-8.RST.7: *Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually*
6-8.RST.8: *Evaluate an author's premises, claims and evidence by corroborating or challenging them with other information*
6-8.RST.9: *Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic*
6-8.W.1: *Write arguments to support claims with clear reasons and relevant evidence*
6-8.W.2: *Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content*
6-8.WHST.2: *Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content*
6-8.WHST.7: *Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of*
6-8.WHST.9: *Draw evidence from informational texts to support analysis, reflection, and research*

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Common Core Mathematics and ELA Standards Reference

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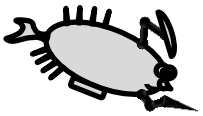
Unit Objectives and Summaries

Unit 1 – Setting the Stage



This unit introduces students to the importance of material properties by having them select appropriate materials for the design of a complex machine operating in a severe environment. Next, students construct a timeline for the wall of their Fusion classroom. In all subsequent activities, developments in the field of materials science will be placed in historical context using this timeline. Finally, students begin to understand the importance of small-scale structure by performing a kinesthetic simulation of atoms forming a crystal. A conceptual understanding of crystalline structure is important to several subsequent activities.

Unit 2 – Ages of Stone and Bronze

This unit begins with an activity in which students examine rocks with differing fracture characteristics which depend on crystalline structure. Students design methods for evaluating which rocks make the best tools for cutting and scraping simulated animal hide. Stone tools were replaced by copper and bronze as soon as people discovered how to smelt ores into metals. Students will study the process of copper smelting and then evaluate the material properties of copper, tin, and bronze.

Unit 3 – Wood Works

Wood has many useful properties, including flexibility. Students will experiment with different techniques for making a permanent bend in wooden craft sticks. Once they master the process, students will design and construct a small wooden ship, using curved timber, which must float and hold a cargo. To keep things water-tight, students will make a tar-like caulking compound.

Unit 4 – The Iron Age

This unit begins with an experiment in which students simulate the heat treatment of steel in an attempt to improve the temper of pasta "sword blades". The next activity examines the chemistry of iron. After examining the smelting of iron ore, student look at the reverse reaction of iron corroding into rust. They will exploit a catalyst's material properties to drastically increase the rate of rust formation. Armed with this experience, students will perform an exercise in forensic engineering to determine why a bridge in Wisconsin recently failed. Finally, they learn about make techniques to make corrosion resistant steel and use their knowledge to identify several samples of unknown metals.

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Unit 5 – Silicates and Light

This unit begins be examining the interactions of matter and light. Students will experiment with a model to learn why materials have such a wide range of visual appearances. Then students will learn about stained glass. After observing patterns in the design work of architect Frank Lloyd Wright, students will use linear equations to design and create their own work of art.

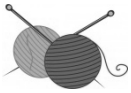
Unit 6 – I'm Rubber, You're Glue

Students will learn why different formulations of rubber have unique material properties. They will make super balls, from both natural and synthetic rubber, and evaluate their performance. Finally they will learn about the deadly ball games played in ancient Mezzo America. Students will build scale models of a ball court and experiment with the rules of these games as an exercise in experimental archaeology.

Unit 7 – Plastic Dreams

Plastics have revolutionized our manufactured world but they have also raised serious environmental issues. Students will examine the chemical and material structure of different plastics. They will perform research before engaging their peers in a debate about one of the many environmental aspects of plastics production, recycling, and biodegradation.

Unit 8 – Textiles



Students take on the role of clothing designers in this problem-centered unit. Customers need fabrics which meet their specific requirements. Before making the best possible recommendations, students will need to perform many experiments to determine the material properties of both natural and synthetic fibers and fabrics.

Unit 9 – Outta this Material World

In this final unit, students examine familiar classroom objects with the eye of a materials engineer. They relate the object's function with its designer's choice of materials. Moving beyond the familiar, students research the most challenging task for a materials scientist, the design of a space suit which protects an astronaut in the extreme environment of space.