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CONSTRUCTION MATERIALS MODULE OVERVIEW

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THEME: Innovation and Progress

LEAD DISCIPLINE: Science

MODULE SUMMARY

We use buildings every day but often take for granted how complex these structures are; this module gives students an in-depth look at the technologies and science necessary to understand these feats of engineering. In this module, students examine properties of construction materials, particularly those of high-rise buildings. Students first learn how high-rises are constructed, the influence these high-rises had on society, and how to communicate complex ideas clearly. Then, students examine the factors behind the collapse of the World Trade Center Twin Towers in New York, focusing on how engineers use failure to learn more about the designed world. Finally, students examine innovations in construction to propose new ways to construct high-rises (adapted from Peters-Burton et al. 2015). (*Note:* Teachers should consider their students' sensitivity to subjects such as the events of September 11, 2001, and terrorism before beginning this lesson. This module may spark emotional reactions, but arguably great learning can happen when people care about the topic.)

ESTABLISHED GOALS AND OBJECTIVES

The first lesson in this module examines the building of high-rises. In science class, students learn about the materials, such as concrete and rebar, used to build high-rises and the forces that must be in place to hold up such structures. In mathematics, students explore the geometry of construction, such as the methods used to place the foundation exactly at right angles. In English language arts (ELA), students learn strategies to gather complex ideas, analyze these ideas, and synthesize them to be communicated clearly. In social studies, students examine the influence that the invention of high-rises has had on societies around the world.

The second lesson focuses on the collapse of the World Trade Center Twin Towers. In science class, students look at the physics and chemistry behind the interactions that led to the collapse, and in mathematics, students concurrently learn about vectors for the purposes of analysis. In ELA, students delve deeper into the concept of success through failure. In social studies, students consider the arguments and sources of those who believe the Twin Towers were brought down by controlled demolition and compare them with mainstream reports of the disaster.

In the third lesson, students look to the future. In science, they synthesize what they learned about current techniques and create innovations for future high-rises. In mathematics, students complete risk-benefit analyses for their innovation ideas, and in ELA, they use effective communication techniques to propose the innovations. In social studies, students conduct a round robin evaluation.

At the conclusion of this module, students will be able to do the following:

- Apply their understanding of the types of materials used to build tall towers and how they are geometrically assembled
- Communicate complex ideas clearly and completely
- Research and describe the reasons communities race to build the world's tallest towers
- Explain the physical analysis of the collapse of the World Trade Center Twin Towers based on published data
- Compare and contrast arguments for the collapse of the World Trade Center Twin Towers
- Synthesize what they learned about current techniques and create innovations for upcoming high-rises

The lessons in this module take into account that it may not be possible for a teacher to collaborate with teachers from other content areas or that teachers from two different subject areas may not have the same students, so teaching in an integrated way in each class may not make sense. Therefore, the lessons are written so that the science teacher can teach the science classes and only a little of each other content area. That is, a teacher who is teaching the module alone may choose to follow only the lead subject, offering enrichment activities in the other connecting subjects. Those who are teaching the modules by themselves may want to collaborate with their peers in the other subjects to get ideas for ways to incorporate the supporting connections seamlessly. Teachers who are able to teach an integrated curriculum can use the module as written for all four subjects in each of the Lesson Plan Components sections of the module.

CHALLENGE OR PROBLEM FOR STUDENTS TO SOLVE: NEW TECHNOLOGIES FOR HIGH-RISE BUILDINGS

Student teams are challenged to use knowledge of molecular-level structure to examine the collapse of the World Trade Center Twin Towers and develop a proposal for new or improved building materials or methods that could be incorporated into the design of future high-rise buildings in U.S. cities.

Driving Question: How can we use what we know about the collapse of the World Trade Center Twin Towers to propose new building materials or methods that could prevent the extent of damage caused by a disaster?

CONTENT STANDARDS ADDRESSED IN THIS STEM ROAD MAP MODULE

A full listing with descriptions of the standards this module addresses can be found in the appendix. Listings of the particular standards addressed within lessons are provided in a table for each lesson in Chapter 4.

STEM RESEARCH NOTEBOOK

Each student should maintain a STEM Research Notebook, which will serve as a place for students to organize their work throughout this module (see p. 12 for more general discussion on setup and use of this notebook). All written work in the module should be included in the notebook, including records of students' thoughts and ideas, fictional accounts based on the concepts in the module, and records of student progress through the EDP. The notebooks may be maintained across subject areas, giving students the opportunity to see that although their classes may be separated during the school day, the knowledge they gain is connected.

Each lesson in this module includes student handouts that should be kept in the STEM Research Notebooks after completion, as well as a prompt to which students should respond in their notebooks. You may also wish to have students include the STEM Research Notebook Guidelines student handout on page 26 in their notebooks.

Emphasize to students the importance of organizing all information in a Research Notebook. Explain to them that scientists and other researchers maintain detailed Research Notebooks in their work. These notebooks, which are crucial to researchers' work because they contain critical information and track the researchers' progress, are often considered legal documents for scientists who are pursuing patents or wish to provide proof of their discovery process.

MODULE LAUNCH

Explain to students the following ideas: Humans make use of buildings daily, usually without giving any thought to the work and ingenuity that created them, and they tend to take the structural integrity of buildings for granted. There also seems to be some status that comes with the building of tall towers, and it is speculated that the attack was made on the World Trade Center Twin Towers because they represented a powerful center in the United States. Post the following thought-provoking statement to engage students in purposeful exploration of the topic: Having the best technologies, such as the tallest building in the world, makes a country powerful. Have students discuss their positions on this statement, the extent to which they agree or disagree, and why. Compile their ideas on the board or in a computer document.

PREREQUISITE SKILLS FOR THE MODULE

Students enter this module with a wide range of preexisting skills, information, and knowledge. Table 3.1 (p. 28) provides an overview of prerequisite skills and knowledge that students are expected to apply in this module, along with examples of how they apply this knowledge throughout the module. Differentiation strategies are also provided for students who may need additional support in acquiring or applying this knowledge.

Table 3.1. Prerequisite Key Knowledge and Examples of Applications and Differentiation Strategies

Prerequisite Key Knowledge	Application of Knowledge by Students	Differentiation for Students Needing Additional Knowledge
Chemical bonding and inorganic chemical reactions	Understand how atoms bond and what inorganic chemicals will react and in what way to be able to understand the composition of concrete and cement.	Review chemical bonding: *www.pbslearningmedia.org/resource/lsps07.sci.phys.matter.chembonds/chemical-bonds* Review chemical reactions: *www.chemtutor.com/react.htm*
Mathematical functions	Understand the role of variables in a function to be able to understand the loads (forces) in constructing static objects.	Review the role of mathematical functions: *www.mathsisfun.com/sets/function.html*
Basic geometry	Understand definitions for and be able to identify a line, plane, and angle so that they can interpret the geometry of tall towers.	Review concepts regarding lines, planes, and angles: *www.virtualnerd.com/pre-algebra/geometry/points-lines-planes-angles*
Molecular structure	Understand how molecules are structured and the macro properties that are a result of this structure. (Different carbon structures such as graphite and diamond are good examples of how the same elements can be arranged differently to produce different properties of the substance.)	Review the shapes of molecules and ions: *www.chembio.uoguelph.ca/educmat/chm19104/shapes_of_molecules_and_ions.htm*

POTENTIAL STEM MISCONCEPTIONS

Students enter the classroom with a wide variety of prior knowledge and ideas, so it is important to be alert to misconceptions, or inappropriate understandings of foundational knowledge. These misconceptions can be classified as one of several types: "preconceived notions," opinions based on popular beliefs or understandings; "nonscientific beliefs," knowledge students have gained about science from sources outside the scientific community; "conceptual misunderstandings," incorrect conceptual models based on incomplete understanding of concepts; "vernacular misconceptions," misunderstandings of words based on their common use versus their scientific use; and "factual misconceptions," incorrect or imprecise knowledge learned in early life that remains unchallenged (NRC 1997, p. 28). Misconceptions must be addressed and dismantled in order for students to reconstruct their knowledge, and therefore teachers should be prepared to take the following steps:

- *Identify students' misconceptions.*
- *Provide a forum for students to confront their misconceptions.*
- *Help students reconstruct and internalize their knowledge, based on scientific models. (NRC 1997, p. 29)*

Keeley and Harrington (2010) recommend using diagnostic tools such as probes and formative assessment to identify and confront student misconceptions and begin the process of reconstructing student knowledge. Keeley and Harrington's *Uncovering Student Ideas in Science* series contains probes targeted toward uncovering student misconceptions in a variety of areas. In particular, Volumes 1 and 2 of *Uncovering Student Ideas in Physical Science* (Keeley and Harrington 2010, 2014), about force/motion and electricity/magnetism, may be useful resources for addressing student misconceptions in this module.

Some commonly held misconceptions specific to lesson content are provided with each lesson so that you can be alert for student misunderstanding of the science concepts presented and used during this module. The American Association for the Advancement of Science has also identified misconceptions that students frequently hold regarding various science concepts (see the links at *http://assessment.aaas.org/topics*).

Students will have various types of prior knowledge about the concepts introduced in this lesson. Table 3.2 (p. 30) outlines some common misconceptions students may have concerning these concepts. Because of the breadth of students' experiences, it is not possible to anticipate every misconception that students may bring as they approach this lesson. Incorrect or inaccurate prior understanding of concepts can influence student learning in the future, however, so it is important to be alert to misconceptions such as those presented in the table.

Table 3.2. Common Misconceptions About the Concepts in This Module

Topic	Student Misconception	Explanation
Engineering design process (EDP)	Engineers use only the scientific process to solve problems in their work.	The scientific method is used to test predictions and explanations about the world. The EDP, on the other hand, is used to create a solution to a problem. In reality, engineers use both processes. (See Teacher Background Information section on p.47 for a discussion of this topic.)
Vectors	Adding the magnitude of vectors gives the resultant vector.	If vectors are located in more than one direction, they need to be translated to the *x*- and *y*-axes separately, then added and resolved into one vector.
Design and building materials	Synthetic chemicals are dangerous.	Many chemicals that are synthesized in laboratories are the same as those produced by nature.
	Vertical loads are the safest structures.	Particularly with tall tower construction, there is a bending momentum, so lateral stability is just as important as vertical stability.