TN Department of Education

Teacher Training
Grade 4

Tennessee Academic Standards for Science

Tennessee Department of Education | Summer 2018

Welcome, science teachers!

We're excited to welcome you to our Teacher Training on the new Tennessee Academic Standards for Science. We appreciate your dedication to the students in your classroom and to your growth as an educator. We hope you are able to use the Tennessee Academic Standards for Science, the eight lessons created by Tennessee educators for your grade level, and the two days of training content, to support your students and serve as a resource to other teachers in your school and district. You do outstanding work every year, and our hope is that the knowledge you gain this week will enhance the high-quality instruction you provide Tennessee's students.

We are honored that the new science standards, training content, and sample lessons were developed by and with Tennessee educators for Tennessee educators. We believe it is important for our standards and professional development to be informed by current practitioners who work each day to cultivate every student's potential.

—Dr. Candice McQueen, Commissioner, Tennessee Department of Education

We'd also like to thank the following subject matter experts for their contribution to the creation and review of this content:

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Peggy Bertrand, Oak Ridge Schools
Jessica Brown, Williamson County Schools
Marsha Buck, Kingsport City Schools
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Jeffrey Cicero, Williamson County Schools
Jeannie Cuervo, Cleveland City Schools
Laura Houston, Hamilton County Schools
Elizabeth Linville, Sumner County Schools
LaToya Pugh, Shelby County Schools
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Digital Training Resources

Access Teacher Training Digital Resources here:

goo.gl/hss2EY **or**

Scan me

Teacher Training Digital Resources

Training Resources	K-12 Science Framework Links	TDOE Science Documents	STEM Teaching Tools
• Training Agenda • Presentation, Manual, and Activities • Three-dimensional Lesson Planning Tool	• NRC Document Cover Page • Science and Engineering Practices • Crosscutting Concepts • Disciplinary Core Ideas ◦ Physical Science ◦ Life Science ◦ Earth and Space Sciences ◦ Eng., Tech., & Applications	• Tennessee Academic Standards for Science • TN Science Standards Implementation Guide • TN Science Standards Reference	• Integrating Science Practices Into Assessment Tasks • Prompts for Integrating Crosscutting Concepts Into Assessment and Instruction

Teacher Training Agenda Day One

7:30–8 a.m.	Sign-in
8–8:30 a.m.	Introduction and Goals
8:30–9:30 a.m.	Three-dimensional Activity
9:30–10:30 a.m.	Three-dimensional Instruction
10:30–10:40 a.m.	Break
10:40–11:30 a.m.	Three-dimensional Instruction
11:30 a.m.–12:45 p.m.	Lunch
12:45–1:15 p.m.	Grade-level Standards Activity
1:15–3:45 p.m. (includes break)	Three-dimensional Learning Activities
3:45–4 p.m.	Closing

Day One Activities

- Learn about the components of the new Tennessee Academic Standards for Science
- Review the science standards for our grade
- Participate in lessons aligned to the new Tennessee Academic Standards for Science

Teacher Training Agenda Day Two

8–8:05 a.m.	Welcome Back!
8:05–11:25 a.m. (includes break)	Three-dimensional Activities
11:25–11:30 a.m.	Morning Debrief
11:30 a.m.–12:45 p.m.	Lunch
12:45–3:45 p.m. (includes break)	Instructional Planning
3:45–4 p.m.	Closing

Day Two Activities

- Participate in lessons aligned to the new Tennessee Academic Standards for Science
- Discuss literacy and instructional strategies in the science classroom
- Utilize an instructional planning tool to plan a three-dimensional learning activity

Standards Timeline

Fall 2018

New TN Science Standards in the Classroom

Spring 2019

Operational Field Test

- Data used to test the reliability of the questions
- No data reported to teachers, schools, or districts
- No accountability measures reported for science
- Grades 3-8 take TNReady field test
- No chemistry EOC field test
- EOC field test for biology
    - Students only take EOC in spring 2019
    - Students taking biology in the fall on a block schedule do not take an EOC

Fall 2019

Second Year of Science Standards in the Classroom

Spring 2020

Fully Operational Test

- Fully operational assessment
- No chemistry EOC

Summer 2020

Standard Setting

- This is the process where Tennessee educators set the performance levels based on the results of the fully operational assessment
- Based on all scores across the state

TN Department of Education

A Framework for K–12 Science Education

Key Terms from the Framework

Term	Notes
Discipline	
Dimension	
Three-dimensional	
Phenomena	
Grade Band Endpoints	

Three-dimensional Science Instruction

Science and Engineering Practices (SEPs)

What will my students **do** to learn science content?

- Asking Questions and Defining Problems
- Developing and Using Models
- Planning and Carrying Out Investigations
- Analyzing and Interpreting Data
- Using Mathematics and Computational Thinking
- Constructing Explanations and Designing Solutions
- Engaging in Argument from Evidence
- Obtaining, Evaluating, and Communicating Information

Notes:

Three-dimensional Science Instruction

Science and Engineering Practices (SEPs)

What will my students **do** to learn science content?

Asking Questions and Defining Problems	***Developing and Using Models***
Planning and Carrying Out Controlled Investigations	***Constructing Explanations and Designing Solutions***

Three Science Words We Should Stop Using

By Rhett Allain, Associate Professor of Physics at Southeastern Louisiana University

Hypothesis:
In my opinion, this one is the worst. The worst science word ever! Well, not ever, but currently. Try this. Find some people and ask—what is a hypothesis? Just about everyone you ask will say:

> *"A hypothesis? That's easy. A hypothesis is an educated guess. BOOM! Give me another easy question."*

This is exactly why we should abolish this word. It has been reduced to a word association game. What is an educated guess anyway? That doesn't even make sense. But what about hypothesis testing? What about science fairs? How can we do these things without the word "hypothesis"? I would recommend not requiring science fair posters to use the word hypothesis. As for hypothesis testing—I will let that stay.

What does hypothesis really mean?
Well, from the Middle French *hypothese*, it means the basis of an argument. This isn't so bad, but it does *not* mean a guess. I think the best current use of the word hypothesis is the testable predictions from an idea.

Let's look at an example. Suppose I have this idea that a constant net force on an object will make it go at a constant speed. In that case, my hypothesis will be that if I apply a constant force to an object, it will indeed go at a constant speed. This could be tested in real life.

Theory:
How about we continue to pretend to ask people what this word means. Here is my generic human answer. Yes, I am gearing this response towards the general population in a slightly negative way. I'm sorry about that. I don't mean to say that humans are stupid but rather the use of this word has transformed into a negative use.

> *"A theory is a scientist's crazy idea about how something works. Really, when something is a theory, it may or may not be true. You know, like evolution. It's just a theory."*

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Three Science Words We Should Stop Using

What is a theory?
A theory can be replaced with another word - see below. But as it is, a theory is a scientific idea. It's not just a crazy made-up idea or wild guess. No, it is an idea that is supported by evidence. Does that mean it's true? Actually, science is not about *the truth.* I will talk more about this in a bit.

Scientific Law:
My favorite example of a scientific law is the law of energy conservation. This says that in a closed system, the total energy remains the same. Ok. Now, what is the common idea about laws?

> *"A scientific law is the next phase for a theory. Once it has been proven to be true, the theory becomes a law. This is just like that School House Rock video about how a bill becomes a law. Same thing, except for SCIENCE."*

What is a scientific law?
It's not really an upgraded theory. No, a law is just more like a generalization. The law of energy conservation is general in that it can be applied in many different cases. It can be used when looking at the collision of two particles, or light produced from a lightbulb, or a pot of water boiling on a stove. Does this mean it's true? No, you didn't read my last point where I said that science wasn't about the truth, did you?

One Word to Replace Them All
Take out all three of these "science" words from introductory texts. They do more harm than good. The problem is that people have firm beliefs that they mean something other than what they are supposed to mean. I don't think we can save these words.
We do have a word to replace them. Are you ready? It's the **model** - or you can call it the scientific model if you prefer.

What is a model?
If I say "model," what do you think of? Do you think of a plastic Corvette that you can pick up with your hands? Yep, that's a model. We agree on this idea of a model. Science is all about making models. Sometimes these models are just like tiny plastic cars, but sometimes they can take other forms. Here are some examples:

Three Science Words We Should Stop Using

Physical Model
Look at a globe—you know, of the earth. This is a physical model of the Earth. It has some features that are the same as the Earth (such as the relative locations of the continents)—but it is not the Earth. It doesn't have the same size or density as the Earth. It's clearly not the Earth. The model is still useful even if it isn't the real Earth.

Mathematical Model
What happens when you have a net force on an object?
That force changes the momentum of the object.
I can also write this idea as an equation (or two equations).

$$\vec{F}_{\text{net}} = \frac{d\vec{p}}{dt}$$
$$\vec{p} = m\vec{v}$$

The equation explains the idea. The momentum principle (above) is a great example of a model that is wrong—but still useful. We say that the momentum vector is the mass of the object times its velocity vector. This is very useful, but it doesn't work when the object's speed is near the speed of light. There is a better expression for the momentum that is more valid—but it is also more complicated.

Conceptual Model
If you rub a nail with a magnet, that nail (if it is ferromagnetic) will then also behave like a magnet. The conceptual model for this phenomena is the domain model of magnets. It says that a ferromagnetic material is made of magnetic domains. If these domains are all aligned in the same direction, the material will act like a magnet.

So, how does a model replace the three words I don't like? Well, if we say science is all about making models, you don't have to use the word “hypothesis.” Instead you can talk about the predictions a model makes (testable predictions). A theory is a model, so that would be a one to one replacement. What about laws? I don't think it would be terrible to also replace laws with the word "model.” Really, I doubt I would ever succeed in having people stop calling it "the law of energy conservation.” Even I would have a difficult time at that.

Science is really about making models and about playing. Yes, playing. Playing isn't just for kids; adults just get better toys. I just wish grade-level (and some college-level) books would move away from defining things and stating pieces of science and focus on the playing part. Many science classes as they are taught now are like studying the different parts of a clarinet—but never playing any music.

Three Science Words We Should Stop Using

Hypothesis

Say This:	Not That:

Scientific Law

Say This:	Not That:

Theory

Say This:	Not That:

Three-dimensional Science Instruction

Science and Engineering Practices (SEPs)

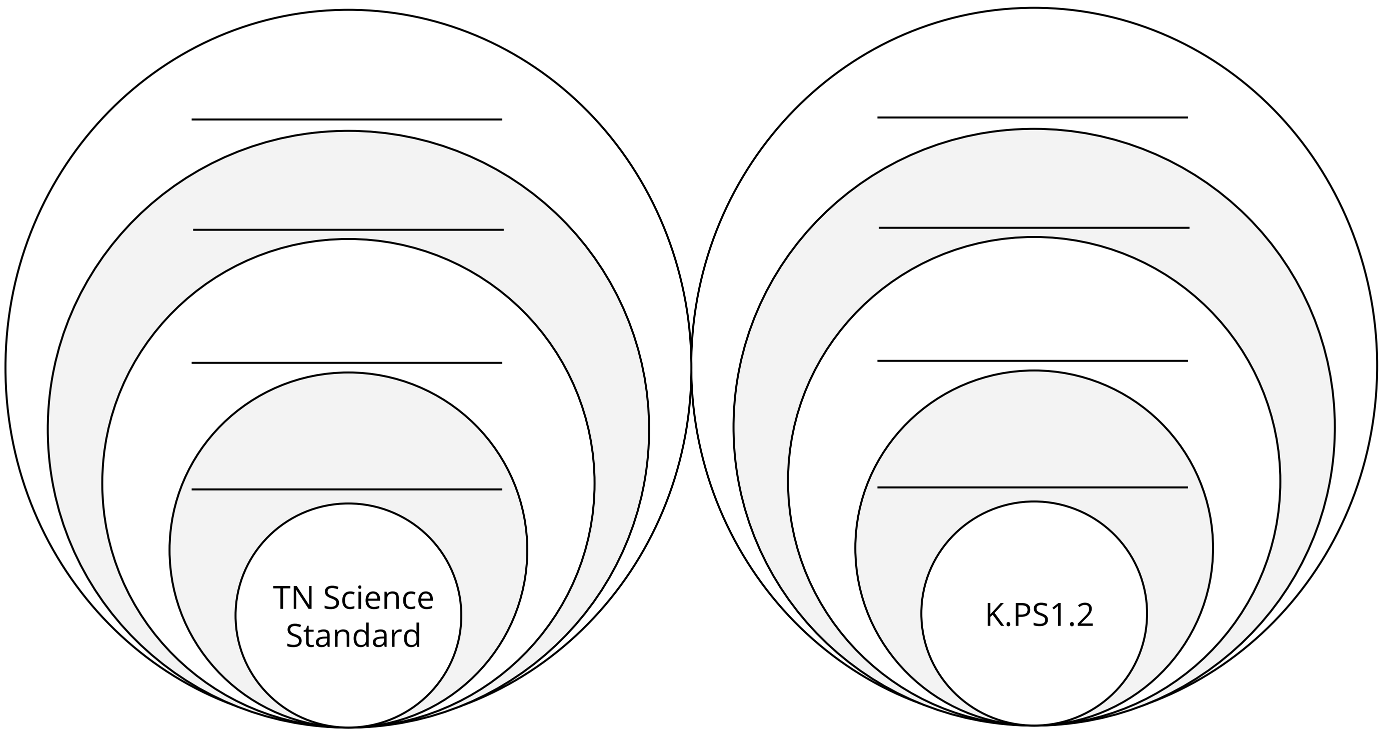
What will my students **do** to learn science content?

Using Mathematics and Computational Thinking	***Analyzing and Interpreting Data***
Engaging in Argument from Evidence	***Obtaining, Evaluating, and Communicating Information***

Three-dimensional Science Instruction

Disciplinary Core Ideas

What science content will my students **know**?



			Standard
			K.PS1.2 – Conduct investigations to understand that matter can exist in different states (solid and liquid) and has properties that can be observed and tested.

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Three-dimensional Science Instruction

Disciplinary Core Ideas

What science content will my students **know**?

Grade Band Endpoints for LS3.A: Inheritance of Traits	Tennessee Academic Standards for Science
By the end of grade 2: Organisms have characteristics that can be similar or different. Young animals are very much, but not exactly, **like their parents and also resemble other animals of the same kind**. Plants also are very much, but not exactly, **like their parents and resemble other plants of the same kind**. (NRC, p.158)	K.LS3.1: Make observations to describe that **young plants and animals resemble their parents**.
By the end of grade 5: Many characteristics of organisms are **inherited from their parents**. Other characteristics result from individuals' **interactions with the environment**, which can range from diet to learning. Many characteristics involve **both inheritance and environment.** (NRC, p.158)	5.LS3.1: Distinguish between **inherited characteristics** and those characteristics that result from a direct **interaction with the environment**. Apply this concept by giving examples of characteristics of living organisms that are influenced by **both inheritance and the environment.**
By the end of grade 8: **Genes are located in the chromosomes of cells**, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of a specific protein, which in turn affects the traits of the individual....**Changes (mutations)** to genes can result in changes to proteins, which can affect the **structures and functions of the organism** and thereby change traits. (NRC, pp.158–159)	7.LS3.1: Hypothesize that the impact of **structural changes** to **genes** (i.e., **mutations**) **located on chromosomes** may result in harmful, beneficial, or neutral effects to the **structure and function of the organism.**

Three-dimensional Science Instruction

Crosscutting Concepts (CCCs)

What will my students **understand** about science?

- Pattern
- Cause and Effect
- Scale, Proportion, and Quantity
- Systems and System Models
- Energy and Matter
- Structure and Function
- Stability and Change

Notes:

Three-dimensional Science Instruction

Crosscutting Concepts (CCCs)

What will my students **understand** about science?

Pattern	***Cause and Effect***
Scale, Proportion, and Quantity	

Three-dimensional Science Instruction

Crosscutting Concepts (CCCs)

What will my students **understand** about science?

Systems and System Models	***Energy and Matter***
Structure and Function	***Stability and Change***

Fourth Grade Standards

4.PS3: Energy

1) Use evidence to explain the cause and effect relationship between the speed of an object and the energy of an object.

2) Observe and explain the relationship between potential energy and kinetic energy.

3) Describe how stored energy can be converted into another form for practical use.

4.PS4: Waves and their Application in Technologies for Information Transfer

1) Use a model of a simple wave to explain regular patterns of amplitude, wavelength, and direction.

2) Describe how the colors of available light sources and the bending of light waves determine what we see.

3) Investigate how lenses and digital devices like computers or cell phones use waves to enhance human senses.

4.LS2: Ecosystems: Interactions, Energy, and Dynamics

1) Support an argument with evidence that plants get the materials they need for growth and reproduction chiefly through a process in which they use carbon dioxide from the air, water, and energy from the sun to produce sugars, plant materials, and waste (oxygen); and that this process is called photosynthesis.

2) Develop models of terrestrial and aquatic food chains to describe the movement of energy among producers, herbivores, carnivores, omnivores, and decomposers.

3) Using information about the roles of organisms (producers, consumers, decomposers), evaluate how those roles in food chains are interconnected in a food web, and communicate how the organisms are continuously able to meet their needs in a stable food web.

Fourth Grade Standards

4.LS2: Ecosystems: Interactions, Energy, and Dynamics—Continued

4) Develop and use models to determine the effects of introducing a species to, or removing a species from, an ecosystem and how either one can damage the balance of an ecosystem.
5) Analyze and interpret data about changes (land characteristics, water distribution, temperature, food, and other organisms) in the environment and describe what mechanisms organisms can use to affect their ability to survive and reproduce.

4.LS4: Biological Change: Unity and Diversity

1) Obtain information about what a fossil is and ways a fossil can provide information about the past.

4.ESS1: Earth's Place in the Universe

1) Generate and support a claim with evidence that over long periods of time, erosion (weathering and transportation) and deposition have changed landscapes and created new landforms.

2) Use a model to explain how the orbit of the Earth and sun cause observable patterns: a. day and night; b. changes in length and direction of shadows over a day.

4.ESS2: Earth's Systems

1) Collect and analyze data from observations to provide evidence that rocks, soils, and sediments are broken into smaller pieces through mechanical weathering (frost wedging, abrasion, tree root wedging) and are transported by water, ice, wind, gravity, and vegetation.

2) Interpret maps to determine that the location of mountain ranges, deep ocean trenches, volcanoes, and earthquakes occur in patterns.

3) Provide examples to support the claim that organisms affect the physical characteristics of their regions.

Fourth Grade Standards

4.ESS2: Earth's Systems—Continued

4) Analyze and interpret data on the four layers of the Earth, including thickness, composition, and physical states of these layers.

4.ESS3: Earth and Human Activity

1) Obtain and combine information to describe that energy and fuels are derived from natural resources and that some energy and fuel sources are renewable (sunlight, wind, water) and some are not (fossil fuels, minerals).

2) Create an argument, using evidence from research, that human activity (farming, mining, building) can affect the land and ocean in positive and/or negative ways.

4.ETS1: Engineering Design

1) Categorize the effectiveness of design solutions by comparing them to specified criteria for constraints.

4.ETS2: Links Among Engineering, Technology, Science, and Society

1) Use appropriate tools and measurements to build a model.

2) Determine the effectiveness of multiple solutions to a design problem given the criteria and the constraints.

3) Explain how engineers have improved existing technologies to increase their benefits, to decrease known risks, and to meet societal demands (artificial limbs, seatbelts, cell phones).

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Why new standards?

What connections can you make from the three dimensions of science instruction (disciplinary core ideas, science and engineering practices, and crosscutting concepts) to the indicators in the TEAM rubric?

- Highlight or annotate evidence of the three dimensions in the rubric.

<table>
<tr><th colspan="2">Instruction</th></tr>
<tr><td>Thinking</td><td>The teacher thoroughly teaches two or more types of thinking:
analytical thinking, where students analyze, compare and contrast, and evaluate and explain information;
practical thinking, where students use, apply, and implement what they learn in real-life scenarios;
creative thinking, where students create, design, imagine, and suppose; and
research-based thinking, where students explore and review a variety of ideas, models, and solutions to problems.
The teacher provides opportunities where students:
generate a variety of ideas and alternatives;
analyze problems from multiple perspectives and viewpoints; and
monitor their thinking to insure that they understand what they are learning, are attending to critical information, and are aware of the learning strategies that they are using and why.</td></tr>
<tr><td>Problem Solving</td><td>The teacher implements activities that teach and reinforce three or more of the following problem-solving types:
Abstraction
Categorization
Drawing Conclusions/Justifying Solutions
Predicting Outcomes
Observing and Experimenting
Improving Solutions
Identifying Relevant/Irrelevant Information
Generating Ideas
Creating and Designing</td></tr>
</table>

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What connections can you make from the three dimensions of science instruction (disciplinary core ideas, science and engineering practices, and crosscutting concepts) to the indicators in the TEAM rubric?

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Instruction	
Motivating Students	• The teacher consistently organizes the content so that it is personally meaningful and relevant to students. • The teacher consistently develops learning experiences where inquiry, curiosity, and exploration are valued. • The teacher regularly reinforces and rewards effort.
Activities and Materials	• Activities and materials include all of the following: ○ support the lesson objectives, ○ are challenging, ○ sustain students' attention, ○ elicit a variety of thinking, ○ provide time for reflection, ○ are relevant to students' lives, ○ provide opportunities for student-to-student interaction, ○ induce student curiosity and suspense, ○ provide students with choices, ○ incorporate multimedia and technology, and ○ incorporate resources beyond the school curriculum texts (e.g., teacher-made materials, manipulatives, resources from museums, cultural centers, etc.). • In addition, sometimes activities are game-like, involve simulations, require creating products, and demand self-direction and self-monitoring. • The preponderance of activities demand complex thinking and analysis. • Texts and tasks are appropriately complex.

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What connections can you make from the three dimensions of science instruction (disciplinary core ideas, science and engineering practices, and crosscutting concepts) to the indicators in the TEAM rubric?

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Planning	
Student Work	Assignments require students to: • organize, interpret, analyze, synthesize, and evaluate information rather than reproduce it; • draw conclusions, make generalizations, and produce arguments that are supported through extended writing; and • connect what they are learning to experiences, observations, feelings, or situations significant in their daily lives both inside and outside of school.
Assessment	Assessment plans: • are aligned with state content standards; • have clear measurement criteria; • measure student performance in more than three ways (e.g., in the form of a project, experiment, presentation, essay, short answer, or multiple choice test); • require extended written tasks; • are portfolio based with clear illustrations of student progress toward state content standards; and • include descriptions of how assessment results will be used to inform future instruction.

Tab page

Label: Day 2

Teacher Training Day Two

Tennessee Academic Standards for Science

TN Department of Education

Literacy in the Science Classroom

Speaking	Reading
Writing	Viewing
Showing	Listening

TN Department of Education

Instructional Strategies

Spend a Buck

Delivery	What is it worth for memory?	________________
Practice by Doing		
Audiovisual		
Lecture		
Reading		
Teaching Others		
Group Discussion		
Demonstration		

Notes:

Three-Dimensional Instruction

Using a new type of teaching in the science classroom

by Joe Krajcik

Science teaching and learning in the United States are at a pivotal point. *A Framework for K–12 Science Education* (NRC 2012b) presents a new vision for science education that shifts science educators' focus from simply teaching science ideas to helping students figure out phenomena and design solutions to problems. This emphasis on figuring out is new, provocative, and exciting, and it represents a revolution in how we teach science at all grade levels.

In their learning, students must use all three dimensions of the new standards—crosscutting concepts (CCs), disciplinary core ideas (DCIs), and science and engineering practices (SEPs)—in an integrated fashion in order to make sense of phenomena or design solutions to problems (see Duncan and Cavera 2015). Classrooms incorporating three-dimensional learning will have students build models, ask questions, design investigations, share ideas, develop explanations, and argue using evidence, all of which allow students to develop important 21st century competencies such as problem solving, critical thinking, communication, collaboration, and self-management (NRC 2012a). Three-dimensional learning also helps students learn to apply new knowledge to other situations. Every student will benefit from this new instructional approach.

What is different with three-dimensional learning?

When I started my teaching career, I frequently engaged students in labs or had them observe a demonstration so they could experience science first- or secondhand. My focus, however, was on students learning the content rather than on having them make sense of phenomena. Learning content is important and necessary; it gives students usable knowledge of the big ideas of science, which serve as tools for thinking about and figuring out phenomena. However, research clearly shows that learning content alone cannot be separated from the doing of science (NRC 2007). If we want students to learn scientific ideas and apply their knowledge, then they must use the SEPs and CCs with the DCIs together. And to learn to use scientific practices, they need to use them along with DCIs and CCs as they try to figure out phenomena or solve problems. None of the dimensions can be used in isolation; they work together so that students can build deeper understanding as they grapple with making sense of phenomena or finding solutions to problems. As a result, learners can figure out more complex phenomena or design solutions to more perplexing problems.

How often should each dimension be used?

Teachers and administrators often ask how often each of the three dimensions should be used, but this is the wrong question to ask. Rather, you should ask yourself: Are my students engaged in making sense of phenomena or designing solutions to problems? Engaging students in three-dimensional learning isn't an item on a checklist; it is an orientation one takes to science teaching, and it should be used every day. Three-dimensional learning involves establishing a culture of figuring out phenomena or designs to problems where a learner builds on his prior knowledge of DCIs, SEP, and CCs to figure out a phenomena and solve a problem and in the process builds deeper knowledge.

My friend and colleague Michael Novak expressed these ideas well while we participated in a workshop on designing curriculum materials aligned to the *NGSS*. To know whether three-dimensional learning is occurring in a classroom, Michael said that teachers should ask students to explain what they are doing. Ideally, students would say that they are trying to figure out how a phenomenon works or how to solve a problem, rather than saying that they are learning about balancing equations, adaptation, or the water cycle. Figuring out permeates classrooms that focus on three-dimensional learning.

Scientists and engineers work in three dimensions

Scientists and engineers use three- dimensional learning throughout their careers. They talk about and engage in making sense of phenomena, and to do so, they simultaneously use SEPs, DCIs, and CCs to make connections among the science ideas related to their current understanding.

For example, some scientists study the question, “Do decaying maple leaves add to the ecology of lakes?” Scientists know that aquatic plants are essential to the food web of lakes. Some scientists, however, wondered and explored the question, “What role, if any, do trees along the shoreline play in the food web of lakes?” Scientists have now gathered evidence that a major component of organic matter needed for energy, growth, and repair of lake organisms is supplied by trees along the shoreline (NSF 2015). Leaves from trees and other organic matter enter lakes and are used by aquatic animals as a source of food. This new and radical way of thinking about lake food webs required scientists to change their models. To explore this question and gather evidence to support the claim, scientists needed to use DCIs related to the organization of matter and energy flow in organisms (LS1.C), the growth and development of organisms (LS1.B), energy in chemical processes and ever yday life (PS3.D), and chemical reactions (PS1.B), along with various SEPs (e.g., Asking Questions, Analyzing and Interpreting Data, Revising and Constructing Models, Arguing from Evidence) and CCs (e.g., Structure and Function, Systems and System Models, Patterns, and Energy and Matter: Flows, Cycles, and Conservation) (NGSS Lead States 2013).

Bioengineers also try to solve problems, and some are figuring out how to make artificial limbs using “smart skin” that mimics the sense of touch (Wu, Wen, and Wang 2013). To do so, they apply concepts from DCIs related to electrical forces (PS2.B), the structure of matter (PS1.A), optimizing design solutions (ETS1.C), and the structure and function of organisms (LS1.A). They also use SEPs to develop models and design and test solutions, and they apply various CCs such as Systems and System Models, Structure and Function, and Cause and Effect.

As the examples above illustrate, scientists and engineers consistently make use of the three dimensions to make sense of phenomena and design solutions to problems. It isn’t a once-in-a-while activity; it is what they do every day.

Where to start?

To start incorporating three-dimensional instruction into your classroom, look for engaging phenomena or problems that build toward performance expectations.

Take note of the questions students are asking, ones that students can explore over a sustained period of time, and ones for which students can ask and explore sub-questions. In selecting phenomena, be sure that the questions are related to the learning goals toward which you want students to build understanding. Therefore, you should be familiar with the Tennessee Academic Standards for Science before you start thinking about phenomena that students can explore. Figure 1 (p. 52) presents a summary of key characteristics associated with the best types of phenomena and questions to explore in the classroom (Krajcik and Czerniak 2013).

Some potential sources of phenomena that aligned Tennessee Academic Standards for Science include:

1. Your local environment. Students find phenomena and associated questions related to the local environment to be valuable and relevant. In trying to make sense of the phenomena related to their local environment, students can make use of DCIs related to biodiversity (LS4.D), social interaction and group behavior (LS2.D), the role of water in Earth’s surface process (ESS2.C), human impacts on Earth systems (ESS3.C), the structure and properties of matter (PS1.A), and interdependent relationships in ecosystems (LS2.A).
2. Your hobbies. I love to scuba dive. Teaching students the ecology of reefs and the effects of rising temperatures of seawater present fruitful opportunities for exploration. If you like to ride bikes, you might explore why it is important to wear a bicycle helmet, which addresses force and motion (PS2.A) and types of interactions (PS2.B).
3. Current challenges facing our environment. How can we reduce our dependency on fossil fuels? How can we make use of wind and solar power to supply our energy needs? Exploring such questions allows students to delve deeply into several DCIs, including energy transfer (PS3.B), electromagnetic radiation (PS4.B), and human impacts on the environment (ESS3.C).
4. The internet, journals, and magazines. Magazines and journals, such as *Scientific American* and *Science News*, are filled with current ideas about phenomena that scientists are exploring. The National Science Foundation’s Discoveries web page (see Resources) can also serve as a source of ideas.
5. Other science teachers and scientists. Your fellow science colleagues can be rich sources of ideas. Sharing your own ideas with other teachers will enrich the pool of phenomena you can use in your classroom.

Conclusion

Developing a classroom culture that focuses on students using the three dimensions to make sense of phenomena or find solutions to problems will initially be challenging. Many teachers haven't been prepared this endeavor has its advantages. First, all students will develop deeper knowledge of the three dimensions, which will allow them to apply their knowledge to new and more challenging areas. Second, as all students engage in figuring out phenomena or solutions to problems, they will also develop problem-solving, critical-thinking, communication, and self-management competencies. Third, and perhaps most importantly, three-dimensional learning will help foster all students' sense of curiosity and wonder in science. "I wonder how ... ?" and "How might ... ?" are extremely important questions that have largely disappeared from science classrooms. Three-dimensional learning brings the focus back to curiosity and wonderment, and it can support all students in developing a deeper and more useable knowledge of science. ■

FIGURE 1 Characteristics of phenomena and questions

Feasible

- By making sense of the phenomenon, students are building understanding toward various performance expectations.

Worthwhile

- By making sense of the phenomenon, students are building understanding toward various performance expectations.

Contextualized

- The phenomenon is anchored in real-world issues or in the local environment of the learner.

Meaningful

- Learners will find making sense of the phenomena interesting and important.

Ethical

- By exploring the phenomenon, learners do not harm living organisms or the environment.

Sustainable

- Learners can pursue exploration of the phenomenon over time.

Acknowledgments

The author thanks Ann Novak of Greenhills School in Ann Arbor, Michigan, for her helpful comments and editing. The author also thanks Michael Novak, a middle school science teacher at Park View Elementary School in Morton Grove, Illinois, and an adjunct faculty member at Northwestern University in Evanston, Illinois, for his insights.

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National Science Foundation (NSF). 2015. What connects fish and maple leaves? *www.nsf.gov/news/overviews/biology/bio_q05.jsp.*

Wu, W., X. Wen, and Z.L. Wang. 2013. Taxel-addressable matrix of vertical-nanowire piezotronic transistors for active and adaptive tactile imaging. *Science* 340 (6135): 952–95.

Resources

National Science Foundation: Discoveries: *www.nsf.gov/discoveries*

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Article adapted from Krajcik, Joe. 2015. Three-Dimensional Instruction; Using a new type of teaching in the science classroom. *The Science Teacher* (November 2015): 50-52."

Sample Three-dimensional Planning Tool

Underlined text is for additional instructions (or hyperlinks).

Italicized text is the sample response.

Step 1: Select a Standard

Standard:

4.LS2.1: Support an argument with evidence that plants get the materials they need for growth and reproduction chiefly through a process in which they use carbon dioxide from the air, water, and energy from the sun to produce sugars, plant materials, and waste (oxygen); and that this process is called photosynthesis.

Step 2: Identify and Break Down Disciplinary Core Idea

A. Identify Disciplinary Core Idea and (Optional) Component Idea

Disciplinary Core Idea:

LS2: Ecosystems: Interactions, Energy, and Dynamics

Component Idea: (optional)

LS2.B: Cycles Of Matter and Energy Transfer in Ecosystems

B. Break Down Disciplinary Core Idea and (Optional) Component Idea

What content could be covered within this disciplinary core idea and (optional) component idea?

This area is for brainstorming content and clarifying ideas.

- *Needs of plants for survival*
- *Plants take in air and water and use light and minerals for growth*
- *Plants acquire materials for growth from the air (carbon dioxide) and water*
- *Photosynthesis is the process that allows plants to use the energy from the sun to grow and maintain internal conditions*
- *Sugar (glucose) as food source for plants*
- *Role of light (as energy from the sun) in photosynthesis*
- *Distinguishing between role of soil and water in plant growth/photosynthesis*
- *Oxygen is released during photosynthesis*
- *Environments needed for plants to grow.*

Sample Three-dimensional Planning Tool

C. Identify Instructional Focus

What content will be the focus of this lesson?

<u>The content only needs to focus on a small part of the standard or disciplinary core idea you are addressing. If you have an instructional focus that that encompasses the entire standard or multiple standards, then that may serve better as a multi-day lesson or unit.</u>

- *Plants use energy from the sun to produce sugar. The production of sugar in plants allows for the generation of plant materials. (Think about CO_2 as the source of the plant matter)*

Step 3: Brainstorm Instructional Scenarios and Select One to Use

- *Use different colors of light on several plants*
  - *Compare growth using different filters?*
- *Put plants in a jar vs. on a table*
  - *Less CO_2 available leads to less growth*
- ***Plant in a window vs. plant in a closet—Selected***
  - *Same level of CO_2 and water but no energy to start photosynthesis*
- *Use bromothymol blue to show conversion of CO_2 for water plants*

Sample Three-dimensional Planning Tool

Step 4: Identify and Break Down a Science and Engineering Practice

A. Identify a Science and Engineering Practice

Which science and engineering practices lend themselves to the lesson, activity, or the disciplinary core idea?

Consider all that apply and select one for this lesson:

1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics, information and computer technology, and computational thinking
6. Constructing explanations and designing solutions
7. **Engaging in argument from evidence—*Selected***
8. Obtaining, evaluating, and communicating information

B. Break Down the Science and Engineering Practice

Brainstorm how you will have students demonstrate their understanding of the disciplinary core idea through the science and engineering practice. Use the task formats to guide your brainstorming.

Look up your selected practice in STEM Teaching Tools Brief #30: Task Formats for the Science and Engineering Practices, review the presented formats, and select which one will work best for your selected instructional scenario.

Engaging in Argument from Evidence #2:

- ***Describe a phenomenon,***
  - *Plants use energy from the sun to conduct photosynthesis and, therefore, need light to grow.*
- ***ask students to construct a claim about the phenomenon,***
  - *Plants will grow more when placed in a window vs. placed in a closet*
- ***ask students to identify evidence that supports the claim,***
  - *Plants in a window will have a higher mass than those in the closet*
  - *Plants in a window will be taller than those in the closet*
- ***and articulate the reasons for how scientific principle(s) connect each piece of evidence to the claim.***
  - *Plants acquire the materials for growth chiefly from air and water, but they require light to perform the process of photosynthesis.*
  - *Light provides the energy needed to convert carbon dioxide from the air into the sugars needed for plant growth.*

Sample Three-dimensional Planning Tool

Step 5: Identify and Break Down a Crosscutting Concept

A. Identify a Crosscutting Concept

Which crosscutting concept is related to the disciplinary core idea or science and engineering practice?

Consider all that apply and select one for this lesson:

1. Patterns
2. Cause and effect
3. Scale, proportion, and quantity
4. Systems and system models
5. **Energy and matter—*Selected***
6. Structure and function
7. Stability and change

B. Break Down the Crosscutting Concept

Think through how students can show their understanding of the crosscutting concept. Use the question prompts to guide your thinking.

Look up your selected practice in STEM Teaching Tools Brief #41: Question Prompts for the Crosscutting Concepts, review the presented questions prompts, and select which one will work best for your selected instructional scenario.

What kind of material is the plant made of?
Where is the matter coming from that is needed for the plant to grow?
What evidence is there that matter is conserved in these changes?

Step 6: Write a Three-dimensional Learning Performance

Possible Template:

"Students will
Science and Engineering Practice
in order to show
Disciplinary Core Idea
highlighting that
Crosscutting Concept."

Sample:

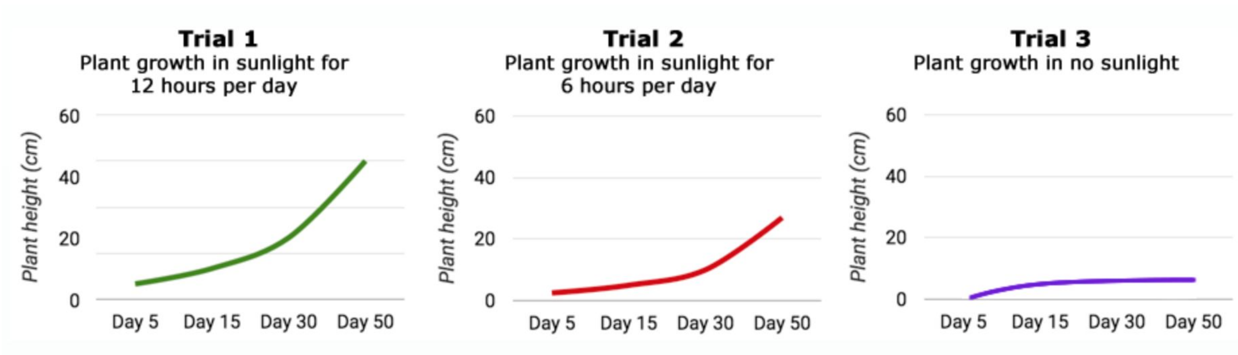
"Students will
compare and refine arguments based on an evaluation of the evidence presented
in order to show
organisms obtain gases and water from the environment and release waste matter back into the environment
highlighting that
matter is transported into, out of, and within systems."

Sample Three-dimensional Planning Tool

Step 7: Write Multidimensional Questions

A. Write a Two-dimensional Question
This question should demonstrate understanding of **the content** presented in the lesson through the use of a **science and engineering practice**.

Josh, Tonya, and Marie analyzed their data after completing an investigation. Based on the data, they all gave explanations to why there is a difference.



Josh: *The reason why there was not a significant increase in plant growth from Trial 1 to Trial 3 is because the plant did not receive enough water, and water is required in order for photosynthesis to begin.*

Tonya: *Plants really do not need light to thrive.The reason why there was a decrease in plant growth from Trial 1 to Trial 3 is due to the fact that the plant was in a closet and not receiving any carbon dioxide.*

Maria: *The reason why there was a decrease in plant growth from Trial 1 to Trial 2 is because the amount of light that the plant is receiving is reduced. Photosynthesis occurs when there is light.*

Using the data above and what you know about how plants grow, which student do you most agree with, and what evidence supports their claim?

Sample Three-dimensional Planning Tool

B. Write a Two-dimensional Question
This question should demonstrate understanding of **the content** presented in the lesson and a **crosscutting concept**.

Jasmine wants to start a learning garden at her school. She has learned that plants have to undergo photosynthesis in order to thrive. However, she is not completely sure what plants need to undergo photosynthesis. She plants four flowers in the outside garden and then conducts four investigations to test how the plants would thrive.

	Plant Consumed			Plant Produces	
	water	air	sunlight	oxygen	sugar
1.	✔	✔	✔	✔	✔
2.	-	✔	✔	-	-
3.	✔	✔	-	-	-
4.	✔	-	✔	-	-

Using Jasmine's data table, explain which plant had what it needed, and describe how you know that photosynthesis occurred. Be sure to include where the plants received their energy, and where the plant matter is coming from.

Sample Three-dimensional Planning Tool

Bullet Point Lesson

Use this space to write a bullet point lesson. Be sure to include an observation-based introduction, student activity, and opportunity for formative assessment.

Your bullet point lesson doesn't need to be this comprehensive, but use this structure to guide your thinking.

http://phenomena.nationalgeographic.com/2016/03/09/the-earth-has-lungs-watch-them-breathe/

- *Show students the image above, and have them jot down only what they see. (3-5 minutes)*
- *Using the same image, have students now jot down what they wonder about what they see. (3-5 minutes)*
- *Have students share their observations and wonderings with a partner, and have them listen to some differences and commonalities in what they see and wonder.*
- *Have students share out their observations and wonderings as a whole class.*
- *The teacher will jot down students questions and wonderings so that it is visible to the class for the duration of the lesson/unit.*
- *Pose the question to students: What does sunlight have to do with how the tree thrived throughout the seasons? (By this time students, should have mentioned something about the presence/absence of the sun.)*

Have students draw an image of the following a) flower, b) sun, c) water, d) soil. At this time, students are just drawing the image and not using arrows or academic vocabulary words to label their drawings. This will come later after they collect additional information through their investigation and research. Have students conduct the sunlight investigation. Students will place one plant in the sunlight (on a window sill) or near a lamp if there is not a window in the classroom. Students will then place another plant in an area without visible light (a closet). Students will water both plants throughout the week and monitor the plant for several days while collecting data.

Sample Three-dimensional Planning Tool

Students will be presented with several resources in which evidence will be collected from and jotted in their notebooks. The following resources can be used:

- *YouTube Video*
  - *https://www.youtube.com/watch?v=D1Ymc311XS8*
- *PBS Learning*
  - *https://tn.pbslearningmedia.org/resource/tdc02.sci.life.stru.photosynth/photosynthesis/#.WvCJOFMvzFQ*
- *Study Jams Video*
  - *http://studyjams.scholastic.com/studyjams/jams/science/plants/photosynthesis.htm*
- *Smithsonian Article*
  - *https://ssec.si.edu/stemvisions-blog/what-photosynthesis*

Using the information from the text and/or video, have students revisit their drawings and have them use arrows and words from their resources to label their drawings. At this point, look for whether students have labeled the flow of the reactants and products from the photosynthesis. The following simulation and can be used if students are having difficulty http://www.biology.ualberta.ca/facilities/multimedia/uploads/alberta/Photo.html.
The students will revisit the data they have collected from the plant they placed in the window sill and the one they placed in a dark area. The teacher will engage the students in a discussion about the data they collected.

- *What patterns do you see in the data collected?*
- *What conclusion can you draw about what would happen to the plant if we allowed it to stay in its location for another week?*
- *Would the results would be the same if they put both plants in the light and changed another variable, such as water?*

Have students complete the formative assessment in step 7.
Revisit the picture of the tree have students use what they know about photosynthesis to answer the following question: What does sunlight have to do with how the tree thrived throughout the seasons?

Three-dimensional Planning Tool

Step 1: Select a Standard

Standard:

Step 2: Identify and Break Down Disciplinary Core Idea

A. Identify Disciplinary Core Idea and (Optional) Component Idea

Disciplinary Core Idea:

(Optional) Component Idea:

B. Break Down Disciplinary Core Idea and (Optional) Component Idea

What content could be covered within this disciplinary core idea and (optional) component idea?

C. Identify Instructional Focus

What content will be the focus of this lesson?

Three-dimensional Planning Tool

Step 3: Brainstorm Instructional Scenarios and Select One to Use

Step 4: Identify and Break Down a Science and Engineering Practice

A. Identify a Science and Engineering Practice

Which science and engineering practices lend themselves to the lesson, activity, or the disciplinary core idea?

Consider all that apply and select one for this lesson:

1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics, information and computer technology, and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Three-dimensional Planning Tool

B. Break Down the Science and Engineering Practice

Brainstorm how you will have students demonstrate their understanding of the disciplinary core idea through the science and engineering practice. Use the task formats to guide your brainstorming.

Step 5: Identify and Break Down a Crosscutting Concept

A. Identify a Crosscutting Concept

Which crosscutting concept is related to the disciplinary core idea or science and engineering practice?

Consider all that apply and select one for this lesson:

1. Patterns
2. Cause and effect
3. Scale, proportion, and quantity
4. Systems and system models
5. Energy and matter
6. Structure and function
7. Stability and change

B. Break Down the Crosscutting Concept

Think through how students can show their understanding of the crosscutting concept. Use the question prompts to guide your thinking.

Three-dimensional Planning Tool

Step 6: Write a Three-dimensional Learning Performance

Possible Template:

"Students will
Science and Engineering Practice
in order to show
Disciplinary Core Idea
highlighting that
Crosscutting Concept."

Step 7: Write Multidimensional Questions

A. Write a Two-dimensional Question

This question should demonstrate understanding of **the content** presented in the lesson through the use of a **science and engineering practice**.

TN Department of Education

Three-dimensional Planning Tool

B. Write a Two-dimensional Question
This question should demonstrate understanding of **the content** presented in the lesson and a **crosscutting concept**.

Bullet Point Lesson

Use this space to write a bullet point lesson. Be sure to include an observation-based introduction, student activity, and opportunity for formative assessment.

Next Steps

Write down 3–5 goals for your science instruction this coming school year.

List 3–5 resources you can use to help you plan for science instruction.

Identify 3–5 people you can go to when you have questions.

Identify 3–5 people you can collaborate with to implement the new science standards.

I used to ____, but now I will

____.

Tab page front

Label: Developing and Using Models

Developing and Using Models

Tennessee Academic Standards for Science

Teacher Guide for Grade 4

Standard
4.PS4.1 Use a model of a simple wave to explain regular patterns of amplitude, wavelength, and direction.

Tennessee Academic Standards for Science: Page 37

Three-dimensional Learning Performance for Lesson
Students will develop and use models* in order to show that amplitude, wavelength, and direction are basic properties of waves,** highlighting that patterns of repeating amplitudes and wavelengths describe a wave.***

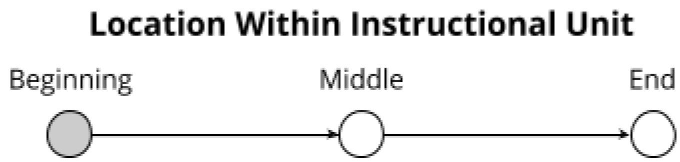
Science and Engineering Practice for Lesson
*Developing and Using Models**
The goal of this three-dimensional learning performance is for students to develop and use models of both transverse and longitudinal waves. Note that wave interactions are not included in this activity.

Disciplinary Core Idea for Lesson
*Physical Science: Waves and their Application in Technologies for Information Transfer***
Waves of the same type can differ in amplitude and wavelength. Waves can add or cancel one another as they cross, depending on their relative phase, but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.)

A Framework for K–12 Science Education: Page 132

Crosscutting Concept for Lesson
*Patterns****
Students will use the models to examine patterns in two basic wave types: transverse and longitudinal. Using these patterns, students will be able to identify and classify wave types as well as make predictions about how changes in energy can affect patterns in wave properties.

Prior Knowledge



- Concepts that should be covered before this lesson:
    - Light and sound can send signals over a distance.
    - Waves move in regular patterns of motion caused by disturbances in a medium.
    - Waves are a way to transfer energy from object to another.
- This lesson covers portions of standard 4.PS4.1:
    - Use a model of a simple wave to explain regular patterns of amplitude and wavelength.

Materials (Note: This lesson can be done as a demonstration if not enough materials are available for students to work in small groups.)

- Wooden skewers (75)
- Duct tape
- Gummy bears (150)
- Rubber duck or other object
- Jump ropes
- Slinkys (metal works best)

Lesson Sequence and Instructional Notes

Begin the lesson by projecting the images from the student activity sheet onto the board. Ask students to think about what properties the images all have in common. The idea is to see if students will recognize that all of the images have something to do with waves: ocean waves, sound waves, and a simple hand wave. Students may also suggest that all have to do with energy and/or motion. All of these ideas are correct and provide opportunity for formative assessment of prior knowledge.

Important: It is essential that students not be given the activity handout until after the images are shown so that they don't just scan the activity sheet and find the word "waves."

Hand out the student activity sheet. Students can record the word "waves" in the square below the pictures of the boat, band, and person waving.

Tell students that the lesson today is all about waves. Explain that you are going to show them several different examples of waves. As they view each example, ask them to look for patterns that they observe in each. Introduce each of the following wave models to the students. Sample guided questions are included after each model.

A. Video Wave Model

   Sample Teacher Questions:
   What patterns do you notice? *The repeating rise and fall of the wave.*
   Pick one person and watch as the motion passes. What do you observe? *The motion moves under the person but does not carry the person along with it. The person moves up and down only.*

B. Kinesthetic Wave Model: Many students have probably seen a "wave" created by participants at a stadium event. If not, a video clip can be shown first as an example. Have students line up and explain to them that they are going to work together to make a wave. Ask one volunteer to hold a rubber duck (or other appropriate object) in his/her hand to resemble one particle that will be affected by the wave. The teacher can be the "initiator" of the wave and serve as the source of energy. As students perform the wave, point out that the rubber duck moves up and down as the wave passes, but does not move from student to student; The duck's position is unchanged. The energy moves from one student to another, but the students themselves (and the duck) do not move with the wave.

C. Gummy Bear Wave Machine Model: Teachers should construct a simple wave machine using wooden skewers and gummy bear candy PRIOR to the lesson. The instructions can be found at this link.

   The videos below are helpful in construction and use of the Gummy Bear Model:

   https://www.youtube.com/watch?v=UWGhMttIUZw or
   https://www.youtube.com/watch?v=VE520z_ugcU

   The following are examples of guided teacher questions that can be asked. Answers are included in italics for teacher background knowledge.

   Sample Teacher Questions:
   What has to happen to start the wave? *There must be an initiating source of energy. A disturbance of some sort must happen to begin the transfer of energy.*
   What happens if we change the beginning height of the first gummy bear?
   Increased energy results in an increased height of the wave.

D. After students have explored all three models of waves, teachers can continue to ask questions to guide students toward an understanding of wave patterns:

Sample Teacher Questions:

- Ask: How can we describe the direction of the energy and the direction of the matter through which the wave passes (the medium)? *All three of the above models are transverse waves. The direction of the energy is perpendicular to the direction of the matter that makes up the wave. For example, the people in the pool go up and down as the wave moves from left to right across the water.*
- Ask: How can we compare these models? *All have repeating patterns of motion. All show energy being moved from one point to another. All show that the material (medium) through which the wave travels does not move with the wave itself.*

Tell students that it is now their turn to try and develop a model of a wave. Students will develop their own wave model (a diagram) on the student activity sheet under part two. At this point in the lesson, students have only been introduced to one type of wave, a transverse wave, and have not been formally introduced to wave property vocabulary. However, this is an opportunity to examine student thinking. Explain that they will have an opportunity to add to and/or revise their models as they learn more information, exactly as real scientists do.

Properties of waves, including explicit instruction of vocabulary terms (amplitude, crest, trough, wavelength, transverse, and longitudinal) can be offered at this point through a variety of formats.

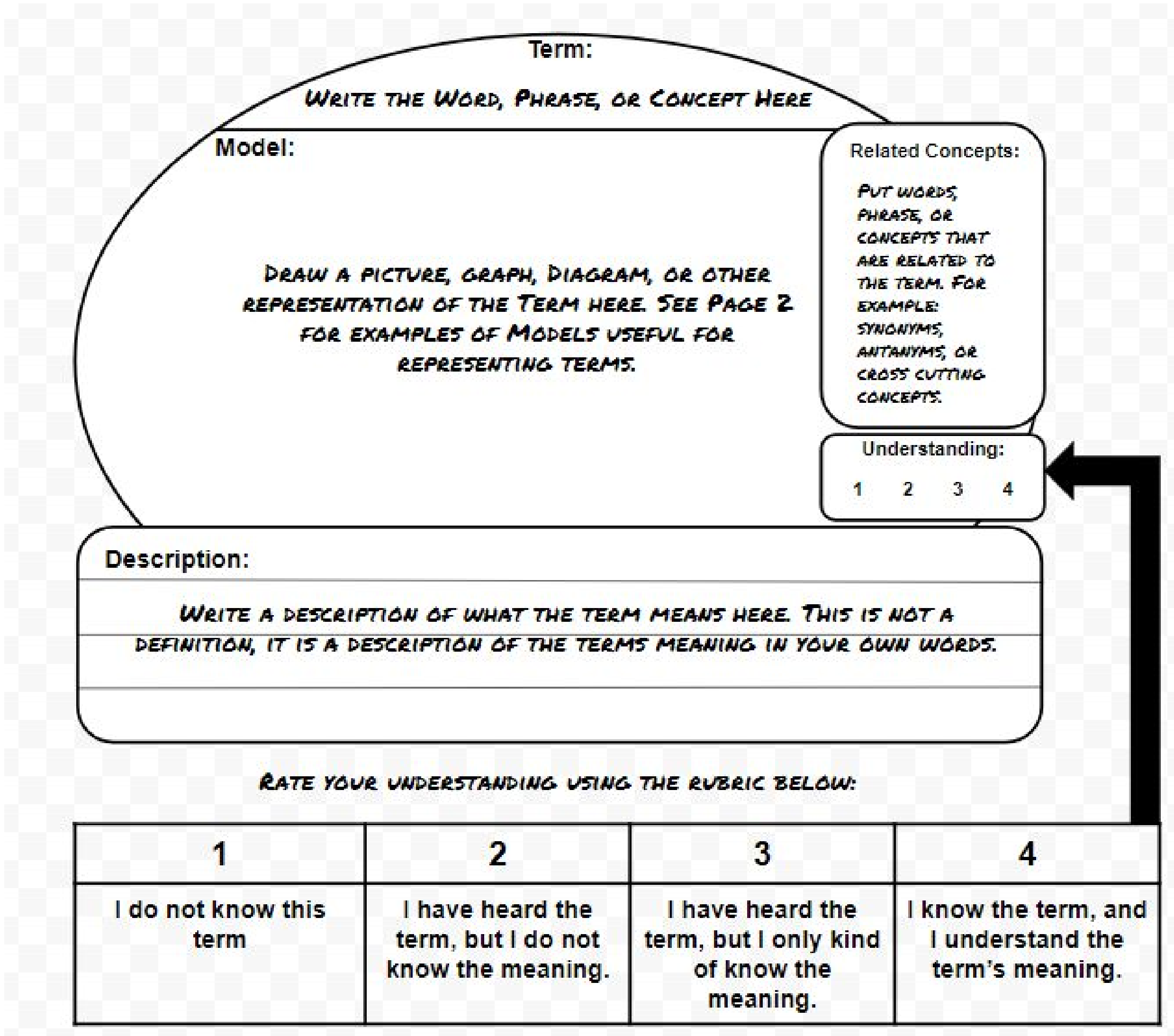
Teachers may choose to show the following video:
https://www.youtube.com/watch?v=Z3O2Ju3ULvo

The following link may also be useful:
http://www.bbc.co.uk/schools/gcsebitesize/science/aqa/waves/generalwavesrev2.shtml.

Also included in the online training hub are two examples of informational text that could be used to introduce vocabulary terms.

After students view the above resources, students should complete the vocabulary models included on the student activity guide under part three. One model should be completed for each of the following terms: amplitude, wavelength, crest, trough, longitudinal, and transverse. Teachers may choose to have students complete this part individually, in pairs, or even working in small groups.

Directions for Vocabulary Model:



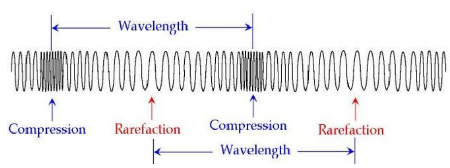
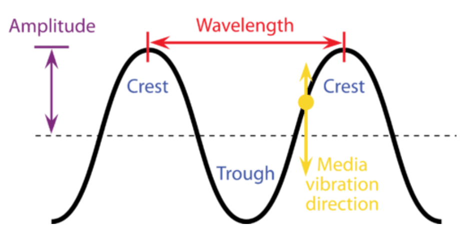
1	2	3	4
I do not know this term	I have heard the term, but I do not know the meaning.	I have heard the term, but I only kind of know the meaning.	I know the term, and I understand the term’s meaning.

Teachers should circulate to check for understanding of basic wave property vocabulary terms.

Students are now equipped with the vocabulary needed to complete part four on the student activity sheet. Students can be organized into small groups and rotate through these activities as stations, or a more guided approach can be done by having the whole class engage in each activity together before moving to the next activity. The advantage of whole class engagement is that each activity can be discussed before proceeding to the next activity. Directions for each activity are included separately. Students will develop a model of each type of wave based on their observations, with emphasis on the patterns apparent in each wave type. In addition, students are asked to think about the limitations that each model has based on their knowledge of wave properties.

It should be noted that at the wave animation station, students are now expected to classify the models that they have seen as part of the lesson, as well as other real-life examples.

Animation: http://www.acs.psu.edu/drussell/demos/waves/wavemotion.html

Wave Type	Particle Model	Particle Motion	Other Models
Longitudinal	 Repeating patterns of particles close together (compressions) and far apart (rarefactions). Pattern of particles of the spring moving parallel to the direction of the energy.	Particle moves parallel to the direction of the wave. Particle's position prior to wave interaction is same as after wave has passed.	Slinky model sound waves: Excellent resource to show sound waves as longitudinal can be found at https://musiclab.chromeexperiments.com/sound-waves
Transverse	 Repeating patterns of crests and troughs. Patterns of particles in the medium moving perpendicular to the direction of the energy.	Particle moves perpendicular to the direction of the wave. Particle's position prior to wave interaction is same as after wave has passed.	People in swimming pool clip. Students acting out stadium wave with the rubber duck. Gummy Bear Wave Model. Jump rope model.

Student responses may vary on the activity sheet. However, the goal of the lesson is for all students to understand the repeating patterns that are found in each wave type, as well as to become familiar with basic wave properties of amplitude and wavelength.

Students are now ready to revise their original model in part five of the student activity sheet. Direct students to the space on the student activity sheet and ask them to develop a model of both a transverse wave and a longitudinal wave. Students should be able to correctly draw and label the parts of a longitudinal wave and a transverse wave. Note: The terms “rarefaction” and “compression” are considered to be enrichment terms at this grade level.

Students end the lesson with an application question in part five.

Suggested Answer: *The motion of the rocks alone would not cause the boat to move appreciably. The rocks would create a disturbance in the water as energy is transferred to the water. The waves would pass under the boat but the boat itself would only bob up and down as the wave passed and would not actually move the boat toward the shore.*

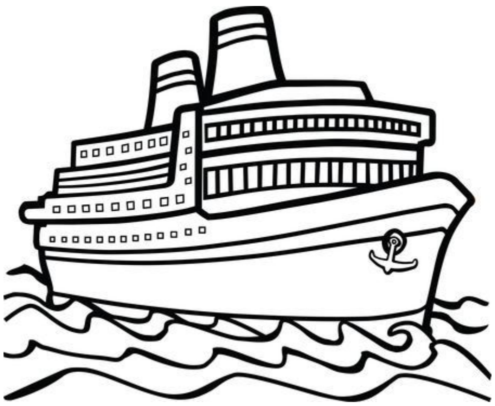
An alternate formative probe is also included in this lesson, which includes additional background information for the teacher.

Resources and Citations

https://www.flinnsci.com/api/library/Download/302eb8450d264a99b0e72b14bcff9994
Vocabulary Graphic Organizer developed by Daniel Way, Kingsport City Schools
http://clipground.com/ocean-waves-black-and-white-clipart.html
http://www.oogazone.com/2017/best-concert-clip-art-black-and-white-vector-pictures/
https://free.clipartof.com/details/1422-Free-Clipart-Of-A-Cruise-Boat
http://www.clipartpanda.com/clipart_images/stock-vector-danger-sign-62797709
http://www.bitesizephysics.com/energywaveslesso.html
http://clipart-library.com/canoeing-cliparts.html
Holt Science and Technology Grade 7 HOLT, RINEHART AND WINSTON; 1 edition (January 1, 2002)

Name ______________________________

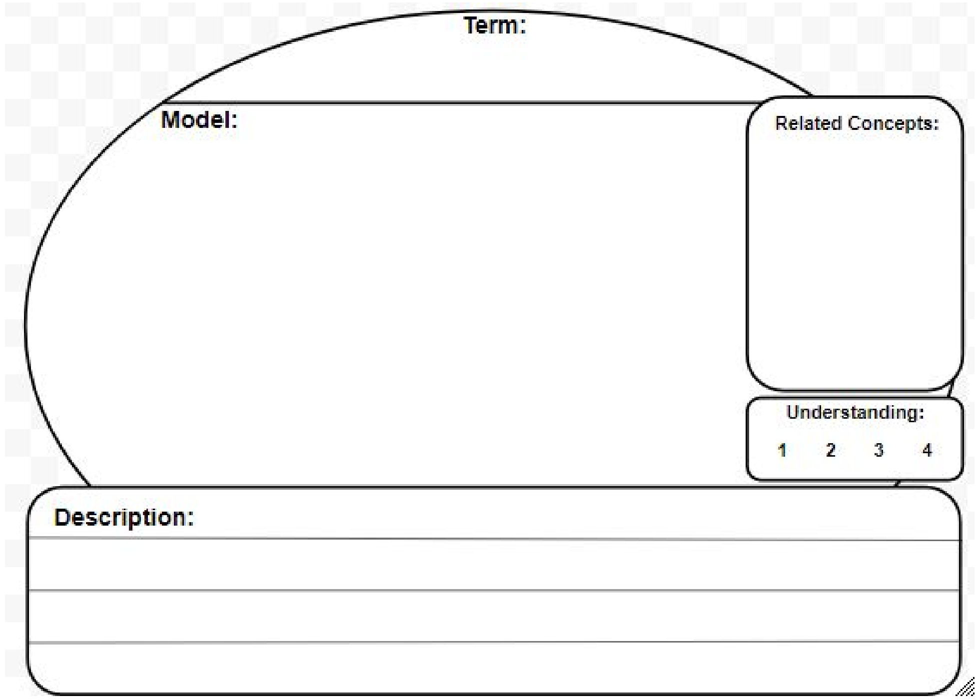
1. Let's observe and analyze. Examine each of the pictures below. In the space provided, write one word that describes a property that all of the pictures have in common.

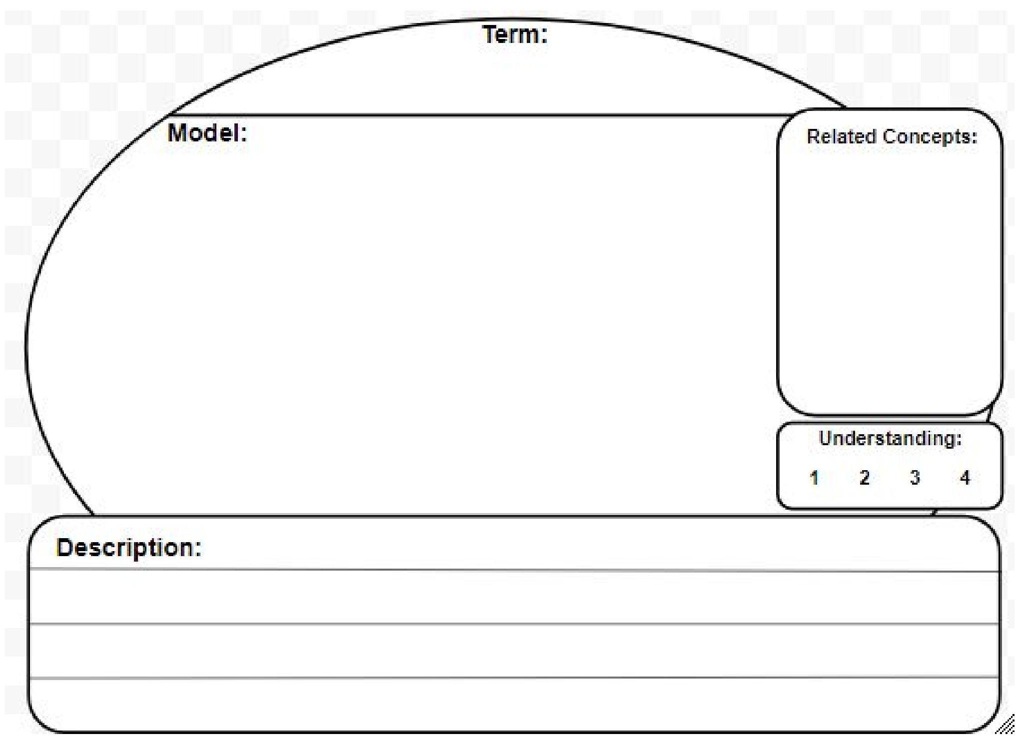


2 Now it's your turn. Let's move some energy! Think about the patterns you observed in each of the waves that your teacher showed to you, and create your own model of a wave. Include in your model a diagram of the wave as it moves under a boat or other object. Indicate the direction of the wave as well as the direction of the object. Show the location of the object both <u>before</u> and <u>after</u> the wave comes in contact with the object.

Before
After

3 Let’s learn. Complete a vocabulary model for each of the following terms: amplitude, crest, trough, wavelength, longitudinal, and transverse.





Term:

Model:

Related Concepts:

Understanding:

1 2 3 4

Description:

Term:

Model:

Related Concepts:

Understanding:

1 2 3 4

Description:

Term:

Model:

Related Concepts:

Understanding:

1 2 3 4

Description:

Term:

Model:

Related Concepts:

Understanding:

1 2 3 4

Description:

4 Let’s explore. Complete each of the following activities to explore the properties of waves.

A. Transverse Wave: Draw a model of the rope (or spring) as a transverse wave. Label the amplitude, wavelength, crest, and trough.

What patterns do you observe in the process of making the transverse wave?

All models have limitations. Identify at least one limitation of this model.

B. Longitudinal Wave: Read and follow the instructions located at the station. Draw a model of the slinky as a longitudinal wave. Label the amplitude and wavelength.

What patterns do you observe in the process of making the longitudinal wave?

Identify at least one limitation of this model.

____

____

____

C. Wave Animation:
http://www.acs.psu.edu/drussell/Demos/waves/wavemotion.html

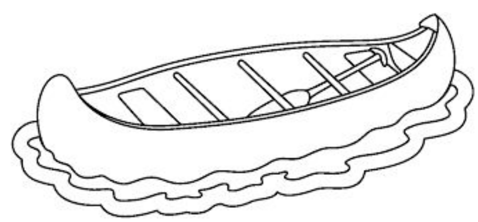
Complete the following table as you observe and analyze each animation:

Wave Type	Particle Model	Particle Motion	Other Models
Longitudinal			
Transverse			

5 Let's revise. In the space below, refine your original wave model from Part 2. Add labels for the parts of the wave. Include arrows to indicate the direction of the wave and the direction of an object on the wave. You have been given space to represent two different wave types.

Transverse
Longitudinal

6 Let's use our knowledge. You have lost the paddles for the canoe you rented, and the canoe has drifted to the center of a pond. You need to get back to the shore, but you do not want to get wet by swimming in the pond. Your friend suggests that you drop rocks behind the canoe to create waves that will push the canoe toward the shore. Will it work? Explain your response to your friend based on your knowledge of wave properties.



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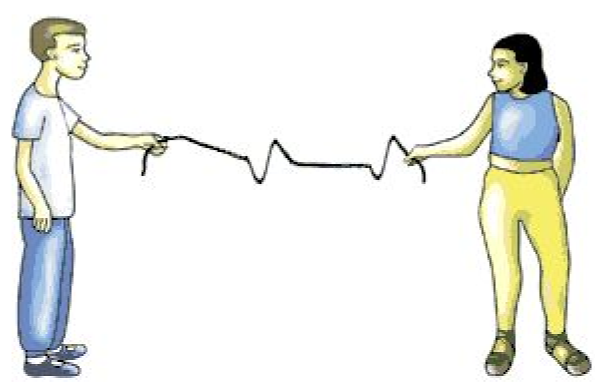
Station 1

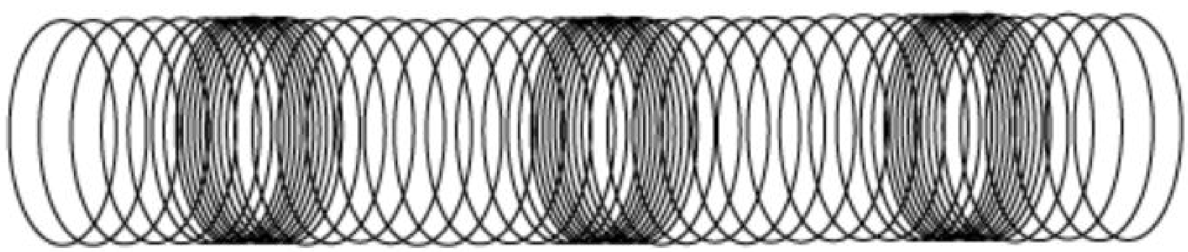
1. Each pair of students will use one rope. Make sure that a piece of tape has been placed in the middle of the rope.
2. Sit down in a designated area with each person holding one end of the rope. You will need enough space to stretch the rope out so that there is only a small amount of slack.
3. While one partner holds the rope still, the other partner should quickly move their arm up and down to begin the wave motion along the floor.
4. Repeat this as you make observations.
5. Move your arm up and down once, and watch what happens.
6. Move your arm up and down several times (not too fast), and observe the results. Notice the action of the tape in the middle of the rope.
7. Try changing the amplitude of the wave by starting with more energy!
8. Repeat the activity, but this time, both partners should stand up with the rope between them.



http://resources.schoolscience.co.uk/Corus/14-16/sound/psch1pg1.html

Station 2

1. Each pair will use one slinky. Please be careful not to pull on the slinky. This will stretch it out too much and damage the slinky.
2. Put a piece of tape on one slinky wire in the middle of the slinky.
3. You can try this experiment with the slinky on the floor between you and also standing up.
4. One partner should hold on to the slinky and not allow it to move.
5. Now stretch the slinky out, but not too far.
6. Quickly push the slinky toward your partner, and then pull it back to its original position. Did you see the wave?
7. Repeat the motion back and forth several times, and observe where the slinky is bunched up and where it's spread out.



https://students.washington.edu/schest/wordpress/2016/06/06/earthquakes-101-seismic-waves/

Station 3 directions are included on the Student Activity Sheet.

Tab page front

Label: Analyzing and Interpreting Data

TN Department of Education

Analyzing and Interpreting Data

Tennessee Academic Standards for Science

Teacher Guide for Grade 4

Standard
4.ESS2.4 Analyze and interpret data on the four layers of Earth, including thickness, composition, and physical states of these layers.

Tennessee Academic Standards for Science: Page 38

Three-dimensional Learning Performance for Lesson
Students will collect and analyze layers of Earth's data[*] to illustrate differences in thickness, composition, and physical state of the Earth's layers[**] highlighting how interactions of the components of the layers work together to define a larger system.[***]

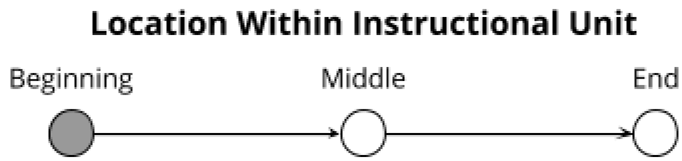
Science and Engineering Practice for Lesson
Analyzing and Interpreting Data[*]
Students should create and analyze graphical presentations of data in ways that highlight statistical features within the data. Students should evaluate multiple data sets for a single phenomenon in order to make comparisons based on a statistical spread of data.

Disciplinary Core Idea for Lesson
Earth and Space Science 2: Earth Materials and Systems[**]
"Earth is a complex system of interacting subsystems. The geosphere includes a hot and mostly metallic inner core; a mantle of hot, soft, solid rock; and a crust of rock, soil, and sediments."

A Framework for K–12 Science Education: Page 179

Crosscutting Concept for Lesson
Systems and System Models[***]
Students group and describe interactions of the components that define a larger system. Students elaborate on the internal structure of the geosphere to include: the crust, mantle, outer core, and inner core.

Prior Knowledge



- Concepts that should be covered before this lesson:
  - N/A
- This lesson covers the following portion of standard 4.ESS2.4:
  - Analyze and interpret data on the four layers of the Earth, including thickness, composition, and physical states of these layers.

Materials

- Earth's Layers Discussion Guide
- 4.ESS2.4_Data_Student Activity
- 4 sandwich size bags per group
- ½ C corn syrup per group
- ½ C soil per group
- ½ C water per group
- 1 ball bearing per group
- 4 Post-it notes per group

Lesson Sequence and Instructional Notes

Student engagement

Pass out the Earth's Layers Discussion Guide. Direct students to independently respond to the initial question: Do you think we can dig a hole to the center of the Earth? Explain why or why not. After giving students two minutes to think through and respond, have students discuss their ideas with their group of three to four students. While students are discussing, have them document any ideas presented in the group ideas discussed row. Monitor group discussions to determine length of time needed for discussion. Once group discussion is complete, have students write down their answer after discussion. This should take just a minute. Continue this process to respond to the second question: Do you think there are structures inside the Earth? If so, what do you know about them? If not, why do you think so?

Distribute the Earth's Layers Viewing Guide. Tell students to document any information about the layers of Earth in the corresponding column. Watch the video: Earth's Interior Isn't Quite What We Thought It Was at https://www.youtube.com/watch?v=IWZky7mXoO0. After viewing, allow students to share information within their group to complete their viewing guide to compensate for anything students may have missed.

Modeling layers of Earth

Prior to class, prepare four bags for each group. One bag should contain about ½ C water, one with about ½ C corn syrup, another with about ½ C soil, and the last with one ball bearing. Measurements are approximate and do not have to be exact.

With the class in groups of three or four, give each group four Post-it notes and four sealed bags: one with water, one with corn syrup, one with dirt/soil, and one with solid iron. Tell students that their task is to identify which layer each bag represents and provide their rationale. Students can label the bags with the layer and the rationale using their Post-it note.

Once groups have completed their labeling and rationale development, lead a discussion with your students to have students share their thinking. Student discussion might include simple ideas like how the crust is like the soil. Their rationale would include that they have evidence for this because they live on the crust and see lots of soil on land. The discussion would continue that there are two solid layers: crust and inner core. In the bags, there are two solid materials: soil and the ball bearing. The inner core is solid metal, so the inner core must be represented by the ball bearing. These are the simplest two connections for students to make. The discussion should continue on to share how students sorted out the water and corn syrup as the mantle and outer core. The corn syrup is thick and moves much more like the mantle. Students may make the connection that they know how lava moves after it is erupted from a volcano. The water represents the outer core, as it is much more fluid. This could be a process of elimination for students if they do not have a formal rationale.

Data collection and assessment

Distribute 4.ESS2.4_Data_Student Activity to students. Students are given a task to investigate the layers of Earth and compile data about physical composition, thickness, temperature, and physical state. Students are given a text and diagram from which to compile their data.

The first question prompts students to go back through the reading and diagram and complete the following:

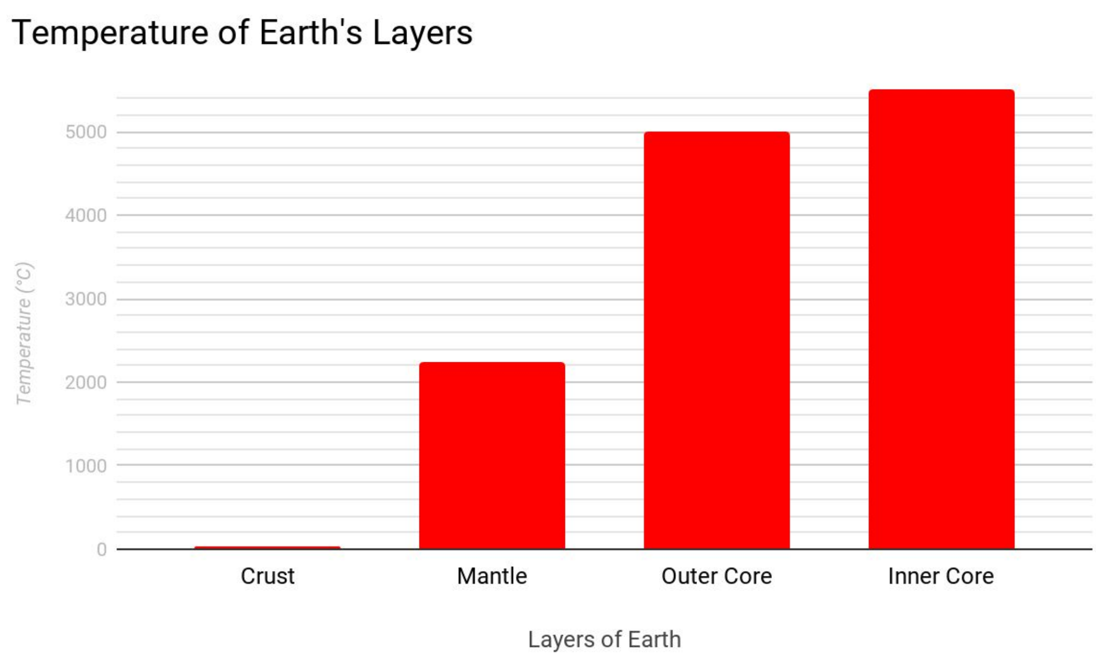
a. Underline the composition of each layer
b. Circle the temperature of each layer
c. Highlight the physical state of each layer
d. Box the temperature of each layer

This will help students in the next question, which asks them to compile this data into a chart. Based on your students' needs, consider pairing or grouping students to complete the initial question.

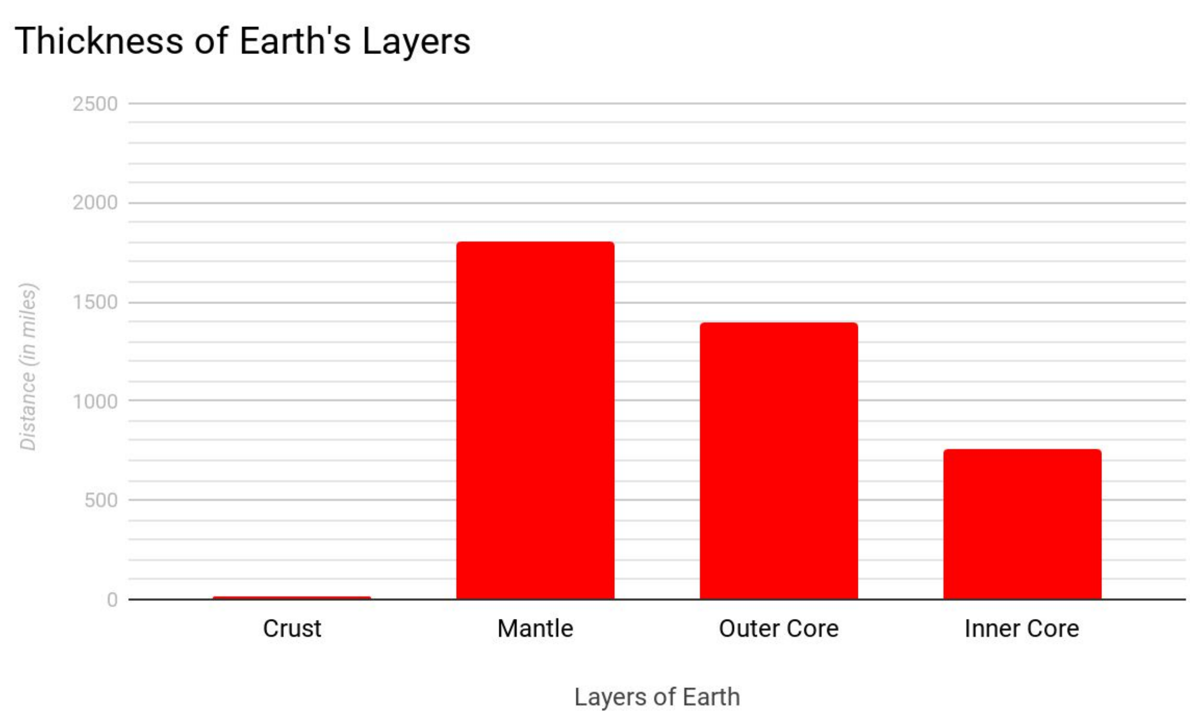
After students have identified the pertinent data, they will fill in the chart in question two. Have students complete this portion independently. The teacher should provide support as needed.

Layer	Composition	Temperature	Physical State	Thickness
Crust	rocks and minerals	around 22°C	solid	3-30 mi (or 2-40 mi based on data from text or diagram)
Mantle	rock	500 to 900°C in the upper mantle and 4000°C in the lower mantle	liquid	1800 mi
Outer Core	iron and nickel	4,000-6,000°C	liquid	1400 mi
Inner Core	iron and nickel	5,000-6,000°C	solid	760 mi

The third question asks students to create a bar graph based on the temperature data they put into their chart. Consider pairing or grouping students for their questions based on their needs.



The fourth question asks students to create a bar graph without the support of the x- and y-axis filled in for them. Have students complete this portion independently. The teacher should provide support as needed.



Upon completion of the chart and graphs, students will write three questions that can be answered by their chart and graphs. Students will also provide the correct answers.

The last question asks students to look back at the original problem. Students are asked to use their charts and graphs to answer the original problem. The students explain what the data is telling them about the problem in the company's design. Students should explain that the design must be able to withstand temperatures in excess of 6,000℃, be able to bore through solid iron and nickel, and move through liquids as well as solids. Their machine must be able to complete all of this with the fuel to travel a 7,900 miles round trip.

Journey to the Center of the Earth

A science research company has decided to build a Geo-explorer capable of navigating the different layers of the Earth. The Geo-explorer must be capable of moving through the different materials, withstanding extreme temperatures, and carry enough fuel to make it through each layer and back. The company has hired you to research the layers of the Earth so that the company will better understand the problems they will face in building their machine. They would like the data you find compiled into an easy-to-read chart. Read the following research and diagrams to gather your data.

Layers of the Earth

Because we cannot go inside the Earth to see what's there, scientists have investigated the composition of the layers of the Earth using seismic waves. As technology improves, new information about the layers of the Earth can be learned.

The Earth is made of four main layers. These layers are the crust, the mantle, the inner core, and the outer core. These layers differ from each other in composition, temperature, physical state, and thickness.

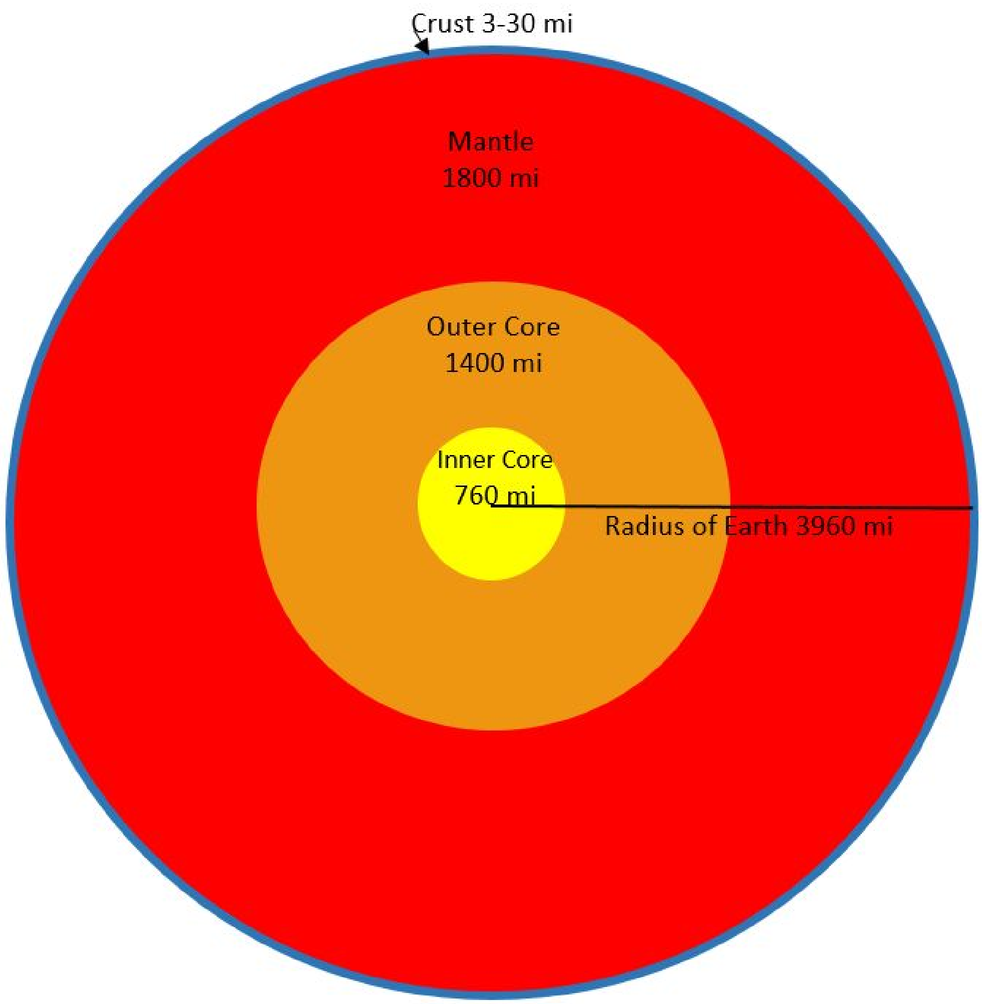
The crust is the layer of the Earth that supports life. Its temperature averages 22°C. It is made of minerals and solid rocks. The crust is the thinnest layer making up less than 1 percent of the Earth's mass. There are two types of crust: oceanic and continental. Land is called continental crust. It ranges from 15 to 40 miles thick. Oceanic crust the crust under the oceans. It is thinner and denser than continental crust. It is around two to six miles thick.

Beneath the crust is the mantle. The mantle is the thickest layer, making up about 72 percent of the mass of the Earth. It is composed of liquid rock made of melted iron and minerals. Intense heat keeps the rock liquid. In the upper mantle, temperatures can range from 500 to 900°C. In the lower mantle, temperatures can reach over 4,000°C. The liquid rock rises and sinks due to changes in temperature. The rising and sinking of the rock causes convection currents. Those convection currents cause movement of the crust on the Earth's surface. The liquid rock can even travel to the surface of the Earth through volcanoes.

Below the mantle is the outer core. The outer core is extremely hot with temperatures reaching 4,000-6,000°C. It is made of iron and nickel. The extreme heat keeps the metals melted into liquid form. The movement of liquid metal causes Earth's magnetic field. The Earth's magnetic field helps protect the Earth from solar winds. Without this protection, life on Earth would not exist.

At the very center of the Earth is the inner core. This layer is the hottest at 5,000-6,000°C. This layer is made of dense iron and nickel. Unlike the outer core, these metals are solid. This layer is hot enough to melt metal, but remains solid due to intense pressure. This layer gives the Earth its gravitational pull.

All of these layers combine to provide Earth's unique qualities. While we know quite a bit about the inside of the Earth, scientists are still investigating to learn more.



Questions:

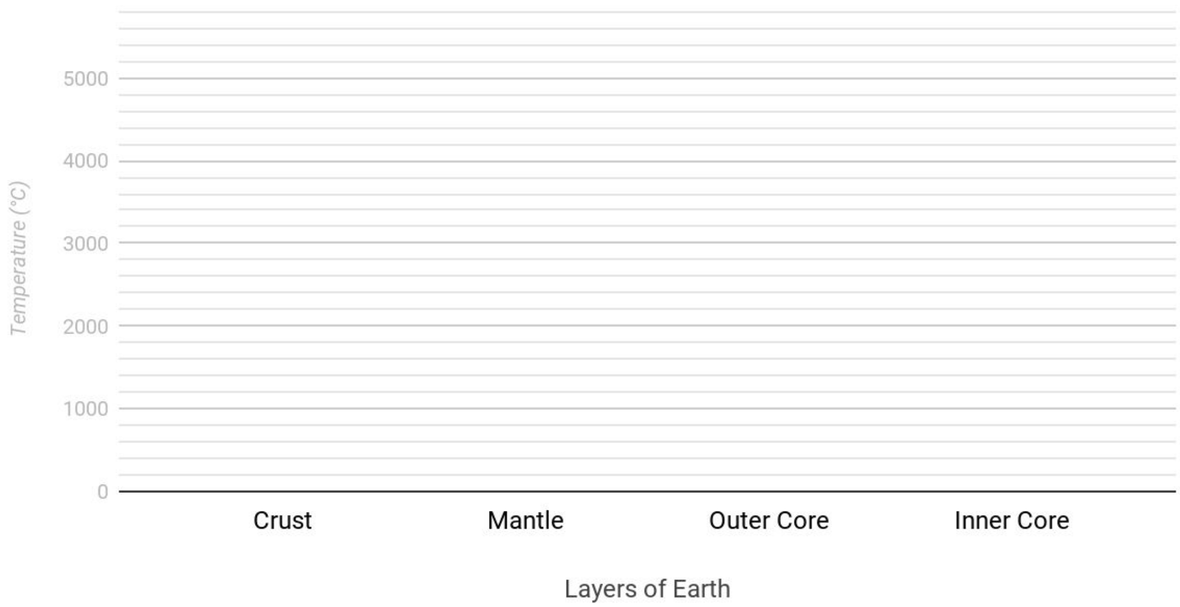
1. Go back through the reading and diagram, and complete the following:
    a. Underline the composition of each layer
    b. Circle the temperature of each layer
    c. Highlight the physical state of each layer
    d. Box the thickness of each layer

2. Complete the following data table about your findings.

Layer	Composition	Temperature	Physical State	Thickness
Crust				
Mantle				
Outer Core				
Inner Core				

3. Create a bar graph for the temperature of each layer. If there is a range of temperatures, graph the average.

Temperature of Earth's Layers



4. Create a bar graph for the thickness of each layer.

5. Write three questions that could be answered by the chart and graphs you created. Also, provide the answer to your questions.
    a. ____

    ____

    ____

    answer:____
    b. ____

    ____

    ____

    answer:____
    c. ____

    ____

    ____

    answer:____

6. The scientific research company really appreciates your hard work compiling data to help with their Geo-explorer design. Now they want you to evaluate what the data is saying. What is the data telling us about the problems the company will face in their design?

    Based on the data the companies design/machine must . . .

    ____

    ____

    ____

    ____

    ____

    ____

Earth's Layers Discussion Guide

	Can scientists dig a hole to the center of Earth? Explain why or why not.	Do you think there are structures inside Earth? If so, what do you know about them? If not, why do you think so?
Explain your thinking		
Group ideas discussed		
Your thinking after discussion		

Earth’s Layers Viewing Guide

Crust	Mantle	Outer Core	Inner Core
Other Interesting facts:			

Tab page front

Label: Asking Questions and Defining Problems

Asking Questions and Defining Problems

Tennessee Academic Standards for Science

Teacher Guide for Grade Four

Standard
4.LS4.1 Obtain information about what a fossil is and ways a fossil can provide information about the past.

Tennessee Academic Standards for Science: Page 38

Three-dimensional Learning Performance for Lesson
Students will formulate empirical questions that lead to accumulating evidence* in order to show that fossils are impressions of types of organisms that lived long ago** highlighting that patterns can be used as evidence to support an explanation.***

Science and Engineering Practice for Lesson
Asking Questions and Defining Problems *
Questions are formulated in a variety of ways, from curiosity, from a model, from theories, and even from attempts to refine a model or theory. The goal of this three-dimensional learning performance is for students to formulate questions based on their noticings and wonderings of fossils. Students should also formulate questions that lead to investigating what fossils are and how they are used to inform us about the past.

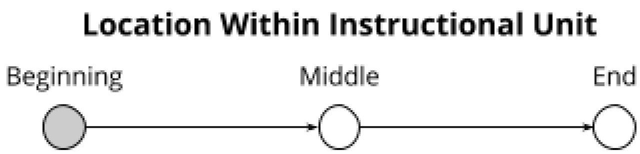
A Framework for K–12 Science Education: Page 55-56

Disciplinary Core Idea for Lesson
*Life Science 4 - Biological Evolution: Unity and Diversity***
“Fossils provide evidence about the types of organisms (both visible and microscopic) that lived long ago and also about the nature of their environments. Fossils can be compared with one another and to living organisms according to their similarities and difference.”

A Framework for K–12 Science Education: Page 162

Crosscutting Concept for Lesson
*Patterns****
When students use patterns to identify similarities and differences, they are able to classify natural phenomenon, and use patterns as evidence to develop a scientific explanation.

Prior Knowledge



- Concepts that should be covered before this lesson:
    - Some kinds of organisms that once lived on Earth have completely disappeared, although they were something like others that are alive today.
    - Most species that have lived on Earth are now extinct.
    - Extinction of species occurs when the environment changes and the individual organism of that species do not have the characteristics necessary to survive.
    - Some kinds of plants and animals thrive, some do not live as well, and some do not survive at all.
- This lesson covers portions of standard 4.LS4.1:
    - Fossils are impressions of plants and animals that lived long ago.
    - Fossils come in all shapes and sizes.
    - Fossils provide information about the past.

Materials

- *What are fossils?* anticipation guide
- Post-its
- Fossil cards
- Fossil card match (teacher answers)
- Evidence collection tool handout
- Fossil card observation activity sheet
- Formative assessment activity
- Access to the internet - https://www.youtube.com/watch?v=1FjyKmpmQzc
- CNN article: "A 6-year-old girl goes digging in the dirt at her sister's soccer game -- and finds a 65 million-year-old fossil"
- Times article: "A Tennessee Girl Discovered a 475 Million Year Old Fossil"
- NEWSELA article "Earth's Systems: What are fossils?"
- Actual Fossils (optional)

Lesson Sequence and Instructional Notes

Activating Prior Knowledge

The teacher will begin the lesson by activating students' prior knowledge about fossils. Activating prior knowledge allows for the teacher to get an idea of what preconceptions students have about the concept. Having a clear understanding of what students know allows for the teacher to address misconceptions and close the content gap(s) throughout the lesson.

For this activity the the teacher will hand out the *What are fossils?* anticipation guide to each student. Inform the students that they are to read the statements in the statement column and then in the before column they are to put a check in the box indicating whether or not they agree or disagree with the statement. The teacher can also read the statements to the class and then have them select the box indicating their point of view. At this moment it is not the role of the teacher to correct any incorrect responses. As students engage in the lesson they will obtain evidence that will guide them to revise any incorrect responses.

Student Directions:

- Read the claim below. If you agree with a claim place a check in the agree column. If you disagree with a claim place a check in the disagree column. You will return to these claims later in the lesson. At that time you will use data collected from the lesson to think about whether you still agree or disagree with each claim (writing your decision in the after column). If you disagree with the claim you will write a revised claim in the space provided. You will also include evidence that supports all of these claims.

After students have selected their responses, inform students that scientists make claims based on previous knowledge and experiences; however, it is important that scientists back up their claims with evidence. Let students know that as they engage in the lesson they will eventually collect evidence, review their claims, and use their evidence to support their initial claim and/or refine their initial claim.

Fossils Found Today

In this phase students will engage in listening to two articles being read to them, by the teacher; one about a 6-year-old girl from Oregon who found a fossil, and another article about an 11-year-old girl from Tennessee who found a fossil. After reading the article have students turn to a neighbor and discuss whether or not they ever poked around in dirt and possibly may have thought they found something interesting, or if not interesting, what was found when they poked around in dirt. After about three to five minutes regain the attention of the whole group and have students share their experiences.

Possible students response:

- I found rocks
- I found sticks
- I found something similar to what Naomi and Ryleigh found
- I found bugs
- I found dirt
- I found glass

After students share, pose the following questions:

- What is unique about Naomi and Ryleigh's findings? *From the text it states that Naomi and Ryleigh found a fossil.*
- Why was Naomi and Ryleigh's finding of their fossil national news? *Naomi's fossil was of a sea creature that went the way of the dinosaurs millions of years ago. Students know that dinosaurs no longer exist and may wonder how this fossil got to Oregon. Ryleigh's was a 475-million-year-old fossil of an extinct marine arthropod that lived in water around east Tennessee millions of years ago.*

Explain to student that as they engage in the next couple of activities they will understand more about fossils. The questions that they will develop will lead them to further investigate the role fossils play in science.

Exploring with fossils

In this phase of the lesson, inform students that you have images of fossils as well as an image of a similar fossil that Naomi and Ryleigh found. Inform students that you are not completely sure what these fossils are, nor what a fossil is. Let students know that you have observed them and have many unanswered questions and predictions about what they could be. Let students know that you want them to observe these fossils too, and you would like them to jot down what they observe and come up with questions that will help them to further investigate what these fossils are. Instruct them to make predictions about what the fossils are using the information from their obserservation.

For this portion of the lesson the teacher will need to print out the fossil cards (*Students will only need the fossil cards, with the fossil length. At this time do not pass out the cards with the organism's name)*. It is recommended that these are printed in color so that student can identify the details of each fossil. This portion could be implemented in a number of ways. Some suggestions are:

A. Provide each student with a set of the fossils and the fossil card observation form. Have each student record their observations, questions, and predictions independently. *The teacher would have to print out a set of cards for each student, which may not be feasible in terms of paper allocation.*

B. Put students into groups of three to four and pass out a set of fossils to each group and a fossil card observation form. Have the group record their observations, questions, and predictions on one form.

C. Due to the number of fossils, place the students in groups of three to four and provide each group at least three fossils to observe and a fossil observation form.

Each group will record their observations, questions, and predictions on chart paper. Some groups may have the same set depending on the total number of students that are in the class. The chart paper will be hung around the room so that all students have an opportunity to visually see the recorded observations, questions, and predictions for each fossil.

As students complete their handouts, create a four squared table with a box in the middle. In the middle of the box, write the question, *What information do we gather from fossils?* This will be the question that drives the lesson, as well as any additional lessons in the unit. After all students have recorded the required information, on their forms, it is essential to review students' observations, questions, and predictions with the class. Pass out three to five Post-it sticky notes to each student. Have them select 3-5 questions from their list and jot one question on each Post-it. Once students have completed filling out their Post-its, have them place it on the class chart *(anywhere on the chart is fine)*. Go over the list of student-generated questions students generated and ask them what they observed to make them generate their question. As you read the questions try to group like questions and form categories *(Categories in the exemplar are examples and do not have to be used. It is important to form categories that are most likely based off the students questions)*. Questions on the question board, that are answered throughout the unit, can be checked off to indicate that students now have the information to provide an explanation to their question.

Possible Student Questions
(As these are possible student questions, these may not be questions your students ask. Embrace all student questions that are asked. If there are some questions that appear to be outliers, place them on a parking lot chart, and inform students that their question will probably fit best in another unit. **Do not dismiss students' wondering and curiosity.**)

- What is a fossil?
- Where were these fossils formed?
- What are fossils made of?
- Why does one fossil look different from another?
- Why are some fossils different colors from the others?
- Is this fossil a plant? Animal?
- Were these fossils buried?
- Are all fossils dinosaurs?

Teacher Moves

- When students share their question say "That is a great question, I was also wondering the same thing."
- If there is a question that may be off from the focus of the lesson, say "What makes you ask that question?"

- Pushing for further clarification around a question, say "Can you share more about what you mean?"

Once all questions are acknowledged and recorded, pass out the cards with the picture of the organism and the organism's name. Inform students that you now want them to observe the details of the fossil and attempt to match them up with the correct organism.

Probing Questions

- Are there any other questions that came to mind as you began to match up the cards? *New questions may arise; questions will vary. If new questions arise these will need to be added to the class question chart.*
- What patterns did you notice that led you to match each fossil image with the organism? *Students may reference the size of the fossil, bones that represent animals, molds/imprints that resemble plants, etc.*
- Where would you think this fossil came from? *Answers will vary*

So What Are Fossils? (Reading Comprehension Activity)

At this time inform students that they have generated a plethora of questions and that scientist consistently generate questions as they further investigate situations that make them wonder. Let students know that although there are so many questions, not all questions will be (nor can be) answered in a day. In order to figure out the answers to questions, it is important to further engage in research and/or investigations.

During this phase let students know that to figure out what these fossils are, it is essential that they know what a fossil is and what significance they have in the field of science as well as geology.

At this time the students will engage in obtaining information about fossils through reading several articles and watching a short clip. There are two different articles that can be read or both can be read as additional evidence.

Resources that can be used for students to obtain evidence:

- ReadWorks: Learning from Dinosaur Fossils
- NEWSELA: Earth's Systems: What are fossils?
- Youtube: https://www.youtube.com/watch?v=1FjyKmpmQzc
- Review of fossil observation form

It is at the discretion of the teacher how to go about having students engage in the resources. The teacher can go through each resource as a class, have students work in groups of 2-3, or have students work independently. The teacher can also go through the video as a class then allow students to work in groups or independently through the text. It is recommended for students who are identified as struggling readers to work in a small group with guidance from the teacher to read through each article.

Literacy Strategies

- Before engaging in the text, have students skim through and identify terms that may be challenging.
- The anticipation guide and the graphic organizer (*Evidence Collection Tool Handout*) should be used to guide students focus to those key topics as they read.

The teacher will provide each student a copy of the *Evidence Collection Tool Handout*. The teacher will go over the directions with the student. At this time it may be helpful for students to model how evidence is to be collected. It is also important to emphasize the need to identify from which resource they received their evidence. This will come back again when they return to their anticipation guide.

Student Directions

- Using your text and your fossil cards obtain information about the fossils in the categories listed below. Be sure to include where you found your evidence.
- After students have their evidence form, the teacher may want to engage students in a whole class discussion as a way to ensure that students recorded accurate information that aligns with the categories provided.

Revisit Questions and Claim Revisions

Now that students have obtained additional information about fossils, revisit the class chart of questions. Identify questions on the chart that students should now be able to answer based on the evidence they collected. Again, the purpose is not to answer all the questions. Some questions that *may be* on the chart that students should be able to answer are:

- What is a fossil?
- Are fossils plants? Animals?
- Why does one fossil look different from another?

After going over the questions and the responses, have students revisit their *What are fossils?* anticipation guide. Inform students to reread their statements. Using their evidence indicated in the after activity column, ask them whether they still agree or disagree with the statement. The statements that students disagree with will need to be revised so that the statement becomes a statement they would agree with. Once statements that are false are revised to true, students will need to include evidence to support why all the statements are now true. Have student refer back to the *Evidence Collection Tool Handout.*

Formative Assessment

Students will be given a picture of a fossil and three images of different organisms. Using evidence, explain which organism represents the fossil.

Criteria:

- Identify the type of organism the fossil represents
- Explain the patterns you observe to identify the similarities and differences in the fossil and organism
- Explain where a paleontologist might find this fossil
- Explain why the other two organisms could not represent the fossil

Teacher Evaluation Notes

- Responses from students who have a full understanding of the learning performance would include in their explanation that the fossil is an impression of picture A, which is a seahorse and an aquatic animal. The fossil and the seahorse have similar features when it comes to seahorses shape, structure and size-as the impression resembles that of the sea horse. Some differences are that the impression of the seahorse in the fossil has a fin, but the actual picture of the seahorse does not, indicating that the fossil is not a replica of the actual seahorse in the picture. Since the seahorse is an aquatic animal, a paleontologist would infer that water once covered the area where the fossil was discovered. Although organism B is also an aquatic animal, it does not resemble the remains of the fossil. Fossils can also be remains of plants. However, this fossil is an impression of an animal. Organism B and C do not share any similarities in regards to structure and size.

Citations and Resources

- https://upload.wikimedia.org/wikipedia/commons/b/b1/Trilobite_clipart.png
- https://www.readworks.org/
- https://newsela.com
- https://www.cnn.com/2018/03/21/health/oregon-child-finds-ancient-fossil-trnd/index.html
- http://www.argumentationtoolkit.org/about.html
- http://www.wisn.com/article/girl-finds-475-million-year-old-fossil-near-tennessee-lake/20130874
- http://time.com/5264880/tennessee-girl-finds-fossil-trilobite/

Name: ___________________

What are fossils?

(Anticipation Guide)

Read the claim below. If you agree with a claim, place a check in the agree column. If you disagree with a claim place a check in the disagree column. You will return to these claims later in the lesson. At that time you will use data collected from the lesson to think about whether you still agree or disagree with each claim (writing your decision in the after column). If you disagree with the claim you will write a revised claim in the space provided. You will also include evidence that supports all of these claims.

Before Activity		Statement	Evidence	After Activity	
Agree	Disagree			Agree	Disagree
☐	☐	1. Fossils are footprints made by dinosaurs. *Revised statement:*		☐	☐
☐	☐	2. Plants do not leave fossils. *Revised statement:*		☐	☐
☐	☐	3. Fossils are all shapes and sizes. *Revised statement:*		☐	☐
☐	☐	4. Fossils can only be made by organisms that lived on land. *Revised statement:*		☐	☐
☐	☐	5. While some fossils are of the actual body of an organism, others are impressions left by the organisms. *Revised statement:*		☐	☐

Adapted from The Regents of the University of California

Name: ____________________

What are fossils?

(Anticipation Guide)

Read the claim below. If you agree with a claim place a check in the agree column. If you disagree with a claim place a check in the disagree column. You will return to these claims later in the lesson. At that time you will use data collected from the lesson to think about whether you still agree or disagree with each claim (writing your decision in the after column. If you disagree with the claim you will write a revised claim in the space provided. You will also include evidence that supports all of these claims.

Before Activity		Statement	Evidence	After Activity	
Agree	Disagree			Agree	Disagree
☐	■	1. Fossils are footprints made by dinosaurs. *<u>Revised statement:</u>* *Possible revision:* • *Fossils are remains or impression of preserved organisms.*	*Evidence will vary*	☐	☐
☐	■	2. Plants do not leave fossils. *<u>Revised statement:</u>* *Possible revision:* • *Fossils are remains of plants and animals*	*Evidence will vary*	☐	☐
■	☐	3. Fossils are all shapes and sizes. *<u>Revised statement:</u>* *No revision needed*	*Evidence will vary*	☐	☐
☐	■	4. Fossils can only be made by organisms that lived on land. *<u>Revised statement:</u>* *Possible revision:* • *Fossils can be made by organisms that live on land and water*	*Evidence will vary*	☐	☐
■	☐	5. While some fossils are of the actual body of an organism, others are impressions left by the organisms. *<u>Revised statement:</u>* *No revision needed*	*Evidence will vary*	☐	☐

Adapted from The Regents of the University of California

Name: ___________________

Evidence Collection Tool

Using your text and your fossil card obtain information about the fossils in the categories listed below. Be sure to include where you found your evidence.

Fossils

What Are Fossils?

Evidence Found:

Fossil Size

Evidence Found:

Fossil Shape

Evidence Found:

Fossil Location

Evidence Found:

Types of Fossils

Evidence Found:

Studies Fossils

Evidence Found:

Name: ___________________

Evidence Collection Tool

(These responses DO NOT serve as an exhaustive list of students responses)

Using your text and your fossil card obtain information about fossils in the categories listed below. Be sure to include where you found your evidence.

Fossils

What Are Fossils?

- Fossils are any evidence of life from long ago.

- Fossils are the remains of ancient life that have been preserved in Earth's Crust

Evidence Found:

- NEWSELA Article (2nd paragraph)
- ReadWorks Article (1st paragraph)

Fossil Size

- Based on my observations of the fossil cards there are fossils that are as small as 2 cm to as large as 243 cm.

Evidence Found:

- Fossil Cards

Fossil Shape

- The shapes of the fossil on the fossil cards are different. The blue fossils reminds me of a shark tooth, and there is also a fossil that looks like the shape of a seashell.

- Fossils come in different shapes because there are fossil remains of plants and animals.

Evidence Found:

- Fossil cards
- Readworks (paragraph 2)

Fossil Location

- Burried in sediment like sand and silt

- Riverbeds are good places for fossils to form.

Evidence Found:

- Readworks (paragraph 3)
- NEWSELA (paragrph 2)

Types of Fossils

- Fossils are both remains of animals and plants

Evidence Found:

- ReadWorks (paragraph 2)

Studies Fossils

- Scientists called paleontologist study fossils.

Evidence Found:

- Readworks (paragraph 4)

Name: ____________________

Fossil Assessment

Below is a picture of a fossil and 3 images of different organisms. Using evidence, explain which organism represents the fossil.

Criteria:

- Identify the type of organism the fossil represents
- Explain the patterns you observe to identify the similarities and difference in the fossil and organism
- Explain where a paleontologist might find this fossil
- Explain why the other 2 organisms could not represent the fossil

<table>
<tr><td rowspan="3"></td><td>A.
</td></tr>
<tr><td>B.
</td></tr>
<tr><td>C.
</td></tr>
</table>

A Tennessee Girl Discovered a 475 Million Year Old Fossil
By ASSOCIATED PRESS May 3, 2018

(DANDRIDGE, Tenn.) — A Tennessee girl's discovery while out walking was eons in the making.

WATE-TV reports 11-year-old Ryleigh Taylor was walking around the shore of Douglas Lake in Dandridge when she found a 475-million-year-old fossil.

The station reports her family reached out to Colin Sumrall, an associate professor of paleobiology at the University of Tennessee to confirm the find. Sumrall said Ryleigh found a trilobite, an extinct marine animal.

Sumall says it's unusual to find a trilobite fossil with all its pieces intact.

Ryleigh says she hopes the discovery inspires other children to go out, enjoy nature and see what they can find.

She doesn't plan to keep the fossil because she wants to see it displayed in a museum so other people can enjoy it.

http://time.com/5264880/tennessee-girl-finds-fossil-trilobite/

A 6-year-old girl goes digging in the dirt at her sister's soccer game -- and finds a 65 million-year-old fossil

By Mercedes Leguizamon and Saeed Ahmed, CNN
Updated 11:06 AM ET, Wed March 21, 2018

Naomi Vaughan, now 7, found an ammonite fossil at her older sister's soccer game last year.

Naomi was bored. A 6-year-old can stay riveted by her older sister's soccer game for only so long.

So she went over to some sagebrush by the soccer field, poked around in the dirt, and picked up a small rock. Something about its swirls reminded her of the mystical necklace from Disney's "Moana."

That was last October.

Earlier this month, Naomi's family learned what the rock really is: a rare, 65 million-year-old fossil.

Something about the rock ...

On that day last year, Naomi needed something to pass the time. Her sister's JV soccer game in Bend, Oregon, was in full swing. So she went digging.

From the looks of it, her mom could tell there was something special about Naomi's "Moana rock."

"She knew it right away," Naomi's dad, Darin Vaughan, told CNN. "I'm not sure I would've."

What the girl had found was the fossil of an ammonite, a sea creature that went the way of the dinosaurs millions of years ago.

But the confirmation led to another head-scratcher: How did it end up in Oregon?

... and what it means for a girl

Greg Retallack, director of paleontological collections at the University of Oregon's [Museum of Natural and Cultural History](), told CNN that ammonite fossils are common but not in Bend.

The ammonite fossil.

In some cases -- some extremely rare cases -- ammonites can fetch between $40,000 to $50,000. But because there's so little known about Naomi's fossil, it's not scientifically significant, Retallack said.

But it's invaluable in another respect: what a find like this can mean to an inquiring young mind.

"This is how we all start," he said.

Retallack's own career as a paleontologist dates back about 60 years. He was 6 years old when he found his first fossil -- a shell on the beach.

"And I never looked back," he said.

There's no telling what the future holds for Naomi, now 7. For now, she's just happy she gets to keep her fossil.

"She's been thrilled to have discovered a fossil," Vaughan, her dad, said. "She's certainly the only person in our family to make that discovery."

Retallack said he hopes to see Naomi someday -- as a student in Oregon's paleontology program.

Earth's Systems: What are fossils?

By Encyclopaedia Britannica, adapted by Newsela staff
Word Count 778
Level 840L

The fossil of a fish called Priscacara that lived more than 33 million years ago. It is now extinct. The fossil was found in Wyoming. Photo from: Wikimedia Commons.

Fossils are the remains of ancient life that have been preserved in Earth's crust. Most people think of fossils as preserved bones or shells of ancient animals. However, there are many forms of fossils. Scientists have even found fossils of early forms of bacteria.

Not all remains of living things become fossils. To form a fossil, an organism must be preserved soon after it dies. If it is not preserved, its tissues will quickly decay. Moist areas such as riverbeds are good places for fossils to form. The most common fossils come from hard tissues, such as shells, bones and tree trunks. Soft tissues can become fossils if they are preserved quickly after the organism dies. However, this is relatively rare.

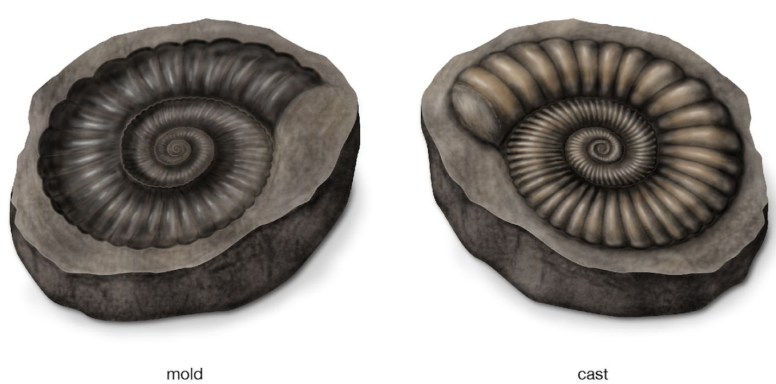
Scientists have found fossil remains of thousands of organisms that lived in the past. Together these fossils make up the fossil record. This is the main source of information about the history of life on Earth. But the fossil record does not include everything, because fossils form only under certain conditions. The record reflects just a small part of all the organisms that have ever lived.

How Fossils Form

There are several ways that fossils can form. One way is called permineralization. This begins when an organism dies in an area such as a wetland and its body is buried under layers of sediment. Sediment includes material like silt, sand and gravel. Over time, more and more sediment presses down on the organism's tissues. The tissues are gradually replaced with minerals from the water that leaks through the sediment. Eventually the remains become petrified, or stone-like. This can take thousands to millions of years. Bones, teeth, shells and tree trunks are generally preserved through permineralization.

Casts and molds preserve a 3-D impression of remains buried in sediment. Water moving through the sediment gradually dissolves the original tissue of the organism. The mineralized impression of the organism left in the sediment is called a mold. The sediment that fills the mold also becomes mineralized. In this way the sediment recreates the shape of the remains. This is called a cast. Ancient sea creatures were

Fossil mold and cast

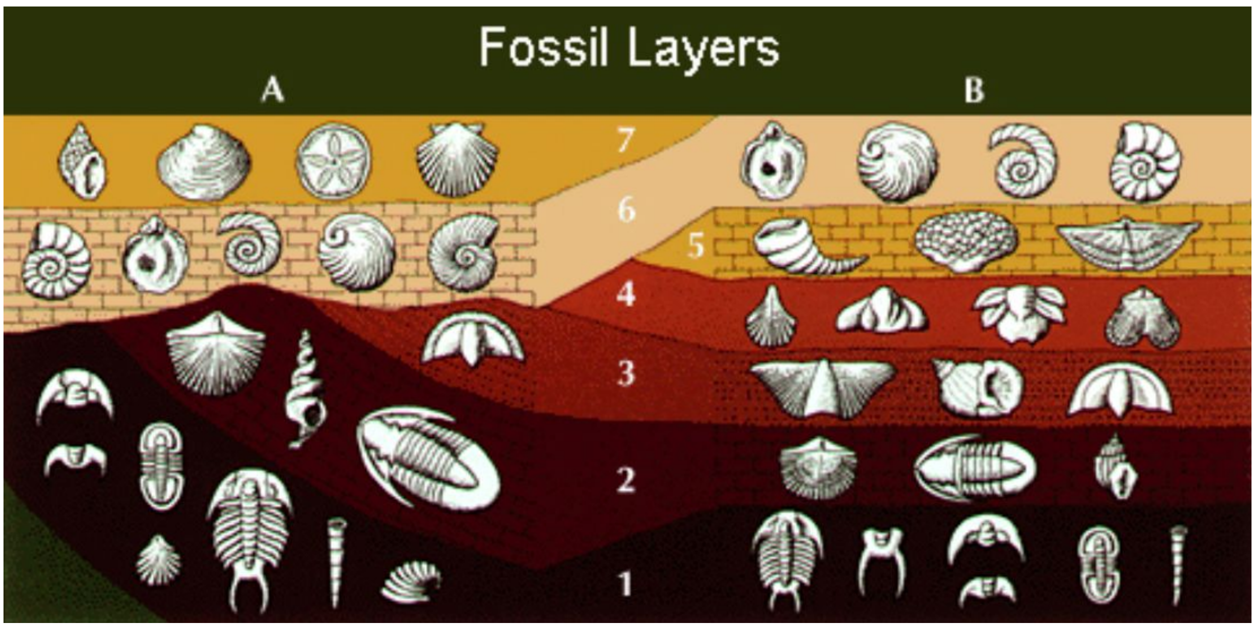


commonly preserved as molds and casts.

Trace fossils provide evidence of an organism's activity. Preserved footprints, trails and nests are trace fossils.

Soft tissues may be preserved through carbonization. These include tissues such as leaves, stems, seeds, insects and feathers. During carbonization, the remains are squeezed between two layers of rock. Chemical changes produce a print-like carbon film on one layer of rock. An impression of the remains occurs on the opposite rock layer.

An object trapped inside a preserved material forms an inclusion fossil. Insects preserved in amber are examples of such fossils. They occur when insects become trapped in the sticky resin of a tree. Over time, the resin hardens into amber.



The Fossil Record

The fossil record shows us what organisms looked like a long time ago. Many of these organisms are no longer alive today. The fossil record shows how the animals evolved over time from one animal into another.

The fossil record goes back more than 3 billion years. The oldest known fossils are tiny creatures that look like bacteria. Other ancient fossils look like jellyfish, sea anemones and worms.

What Fossils Teach

Scientists use fossils to learn about ancient organisms and the ancient world. Fossils provide evidence of ancient climates and ecosystems. They also show how the land has changed over time. For example, there are fossils of sea creatures high up in the Himalayas, Alps and Rocky Mountains. This shows that these great mountains were once under the sea.

Some scientists study certain kinds of fossils. Paleozoologists study the fossils of ancient animals, while paleobotanists study the fossils of ancient plants. The fossil record helps paleogeographers study landforms. It shows them how Earth's geographical features have changed over time.

Fossils Cards

6 centimers (cm)

7 centimeters (cm)

5 centimeterrs (sm)

2 centimeters (cm)

60 centimeters (cm)

15 centimeters (cm)

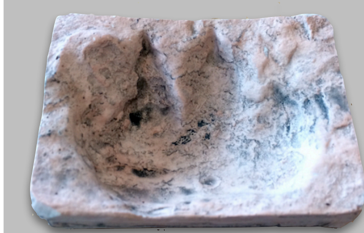
5 centimeters (cm)

8 centimeters (cm)

* Best if printed in color

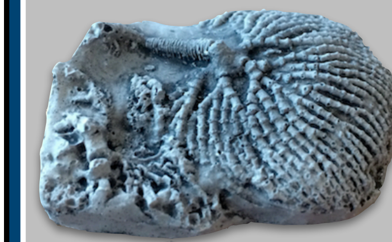
Fossils Cards

3 centimeters (cm)

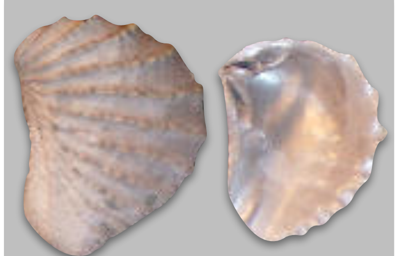


15 centimeters (cm)

2 centimeters (cm)



91 centimeters (cm)



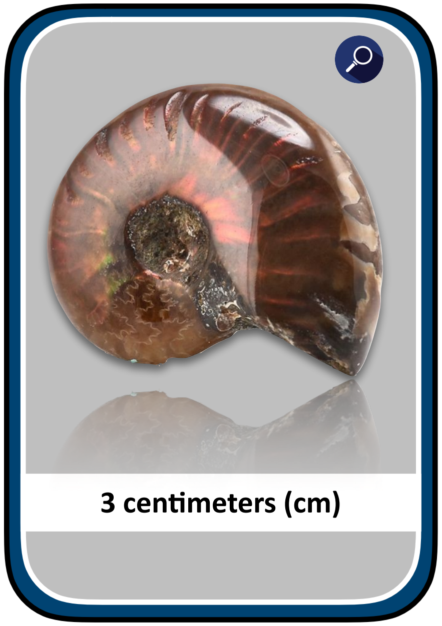
1 centimeters (cm)

2 centimeters (cm)

243 centimeters (cm)

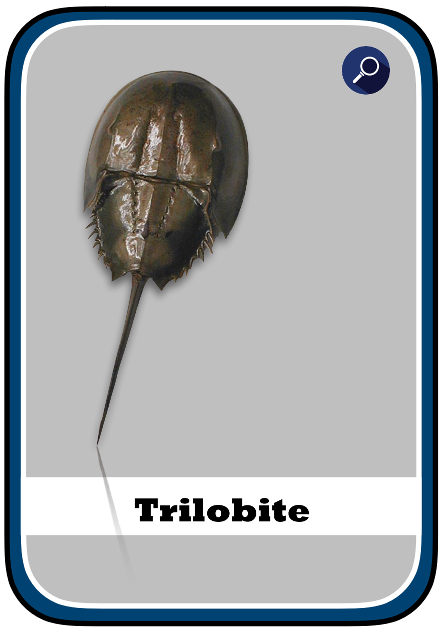
60 centimeters (cm)

* Best if printed in color



* Best if printed in color

Fossils Cards



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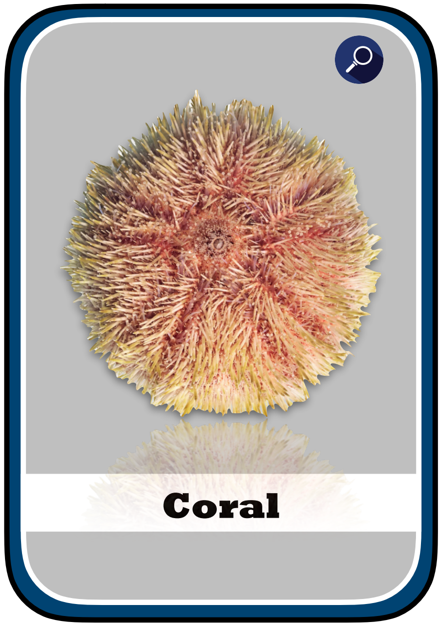
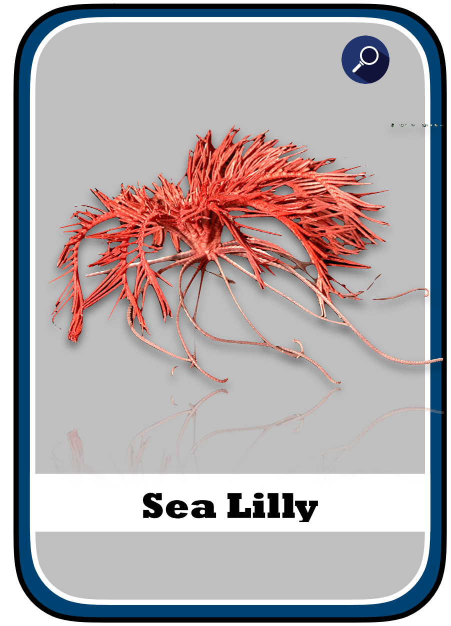
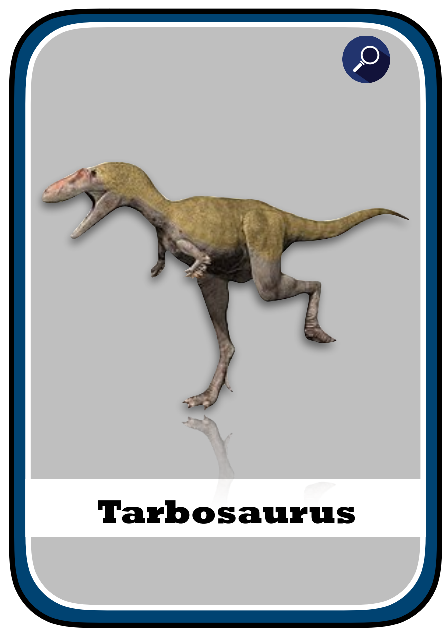
Fossils Cards

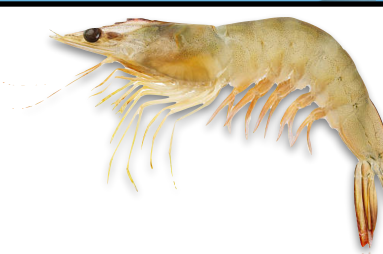


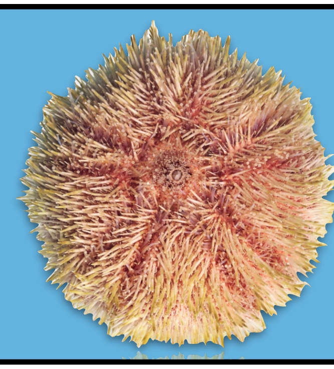
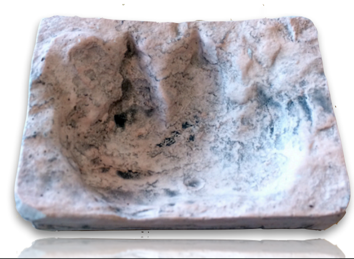
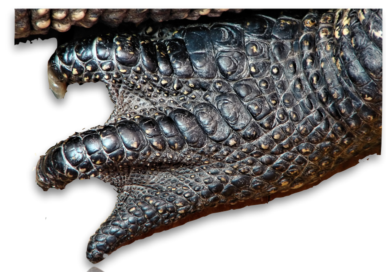
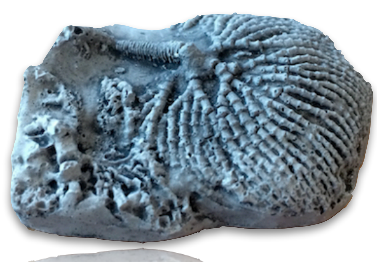




* Best if printed in color

	Fossil	Living Organism
Sea Urchin		
Seed Fern		
Dinosaur Tooth		
Ammonite	 	

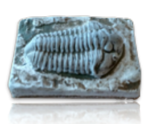
Trilobite		
Fish		
Shark Teeth		
Shrimp		

Coral		
Reptile Foot		
Marine Reptile Tooth		
Sea Lilly		
Ptero		

Fighting Ants		
Tarbosaurus		
Symouria		

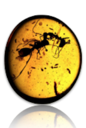
Name: ____________________

Fossil Card Observation Activity

	Observations (What do you notice about this item?)	**Questions** (What questions do you have about this?)	**What I Think This Is?** (What does this remind you of or look similar to?)	**What This Fossil Actually Is?**
				
				
				
				
				
				
				

Name: ______________________________

Fossil Card Observation Activity

Name: ______________________________

Fossil Card Observation Activity

After observing the images of the fossils and the image of the organism that represents the fossil, what patterns did you observe that can be used as evidence to show the similarities and differences in living and extinct organisms?

____

____

____

____

Tab page front

Label: Planning and Carrying Out Investigations

Planning and Carrying Out Investigations

Tennessee Academic Standards for Science

Teacher Guide for Grade 4

Standard
4.PS3.2 Observe and explain the relationship between potential energy and kinetic energy.

Tennessee Academic Standards for Science: Page 37

Three-dimensional Learning Performance for Lesson
Students will plan and carry out investigations* in order to show the relationships between potential and kinetic energy ** highlighting the changes to the energy types present in the system and the ability to transfer energy between objects.***

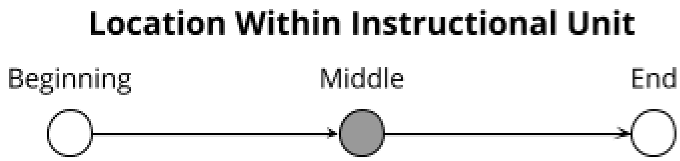
Science and Engineering Practice for Lesson
Planning and Carrying Out Investigations *
The goal of this three-dimensional learning performance is for students to plan and carry out investigations that explain the relationship between potential and kinetic energy.

Disciplinary Core Idea for Lesson
*Physical Science 3: Energy***
“Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed. A system of objects may also contain stored (potential) energy, depending on their relative positions.”

A Framework for K–12 Science Education: Page 123

Crosscutting Concept for Lesson
*Energy and Matter****
When students are able to make explicit connections between the types of energy in a given system and the objects and interactions responsible for each type of energy, they are demonstrating an understanding of the properties and sources of the energy types as called out in the standard.

Prior Knowledge



- Concepts that should be covered before this lesson:
  - The energy of a moving object is properly referred to as kinetic energy. This knowledge is imperative to teaching 4.PS3.2.
  - Students should understand the meaning of potential and kinetic energy.
  - Collecting accurate data
  - Graphing data
- This lesson covers the part of standard 4.PS3.2:
  - After the formative assessment, more instruction on their relationship should occur based on that data.

Materials
- Rubber bands (different sizes)
- Rulers
- Meter sticks
- Popsicle sticks

Lesson Sequence and Instructional Notes

Activating Prior Knowledge

Using a document camera or within a presentation, display to students three to four images. Ask students to think about what the images have in common. Encourage students to think about the kinetic energy they see in their everyday lives, i.e. pouring milk on their cereal, slamming the door, the school bus driving them to school, the soccer ball flying through the air, dropping school books, raising their hand in class, etc. After listening to some of the commonalities that students see, ask the following questions and engage the students in a whole group discussion:

- Do the images represent something in motion?
- What is motion?
- How do you describe it?
- How does motion relate to energy?

After the discussion, write the word ENERGY on the board or on a large sheet of chart paper. Pass out three to four (or more) Post-its to each students. Ask students to think about the word. Inform them to jot down one thought and each Post-it. They can either write what they think the word means, examples of the word, or even questions they may have about energy. As students complete their thoughts on each sticky note, have them place it on the chart paper with the word energy written on it. Once all Post-its are posted, review student feedback. At this time you may want to identify those Post-its that are similar and put them in a group. This way you can see what thoughts and questions are similar amongst the class.

After going through the Post-its, inform students that you would like to use their thoughts, questions, and/or examples to come up with a class consensus for a definition for energy. Have students share their thoughts about what the class definition should be based on the Post-its. After the class has come to a consensus about the definition, inform them that as they work through the lesson they will revisit the class definition to see whether they need to revise it based on new evidence.

Observe The Phenomenon

Inform students that you have a video that you would like for them to watch. Let them know that as they watch the video, you would like them to think about the following questions. You will discuss their responses to the questions after the video.

Video Link- https://www.youtube.com/watch?v=i5-97j0rfU4

Pose the following thought questions to students.

- What did you notice happening in the video?
- What made the pumpkin go as far as it did?
- Do you think it is possible to make the pumpkin go farther or not as far?
- What tool was used in the video?

Planning and Carrying out Investigations

Inform students that you would like them to investigate what was happening in the video to try to explain the science behind how it works. Let them know that they are unable to create a catapult (trebuchet) at that magnitude, however, they can model the same process using different types of materials.

Allow the class to watch the video a second time with the guidance that they should be studying the trebuchet and how it moves, working to understand how potential and kinetic energy come into play. It may be beneficial to “scrub” back and forth across just the launch portion of the video since that occurs so quickly. Allow students time to work together in a small group to diagram the important parts of the trebuchet (names are unimportant) so that they can describe how it functions. Have the groups present their ideas, and during the presentations, ask questions such as:
- What has to be done to get the trebuchet ready to launch?

- How does energy get added to the pumpkin-trebuchet system?
- Where do you see evidence of motion (kinetic) energy during the video?
- Where do you see evidence of stored (potential) energy during the video?

Teacher Set-Up: Rubber Band: Potential and Kinetic Energy Lab

1. Secure a location with an open space for this activity.
2. You will need various size rubber bands.
3. You will need at least one meter stick and one ruler for each group.
4. You will need to demonstrate and explain the data table format to students.

Student Directions

On your ruler, you will be pulling rubber bands back to five different stretch lengths: 10 centimeters (cm), 15 cm, 20 cm, 25 cm, and 30 cm. You will measure how far the rubber bands fly when released from the different stretch lengths and then write your results down in the data table.

Distance (cm)	**10 cm**	**15 cm**	**20 cm**	**25 cm**	**30 cm**
Trial #1	*Answers will vary*	*Answers will vary*	*Answers will vary*	*Answers will vary*	*Answers will vary*
Trial #2	*Answers will vary*	*Answers will vary*	*Answers will vary*	*Answers will vary*	*Answers will vary*
Trial #3	*Answers will vary*	*Answers will vary*	*Answers will vary*	*Answers will vary*	*Answers will vary*
Average:	*Answers will vary*	*Answers will vary*	*Answers will vary*	*Answers will vary*	*Answers will vary*

1. One student will need to stand on one side of the room with the materials that were handed out by the teacher. The other student will need to stand on the other side. Ensure that the student on the receiving end of the rubber band is not directly in your line of fire! The student without the materials will be responsible for marking where the rubber band lands, during each trial.

2. Put a piece of tape on the ground, this is where you will line your feet up when you test your rubber bands. This is also where you will begin measuring the distance in which your rubber bands have gone.

3. Test the distance your rubber band travels by hooking it on the front edge of the ruler, then pulling back to your first length (10 cm) on the ruler and then let go of the rubber band ensuring no one is in the direct line of the rubber band. Remember the angle and height you hold the ruler, because you will need to keep it the same for each rubber band launch.

4. Have your partner mark where the rubber band lands and measure the distance from the starting line to the location the rubber band landed. Record your measurement in your data table.

5. Repeat the steps five times for each of the centimeter marks. As you continue to test, think about whether all three trials have similar launch distances, or was there a lot of variation in how far the rubber bands flew? Average the data from these three trials to get an average distance of each of the cm marks.

6. Repeat the steps but use a different stretch length each time. For example, after you have done three trials for the 10 cm stretch length, do three trials for the 15 cm stretch length, then the three trials for the 20 cm stretch length, etc.

7. Stop after you have done three trials for the five different stretch lengths. Be sure to average your results for each stretch length. Pick a different size rubber band. Complete all the steps again.

While students are collecting data, please monitor for the following:

- No one is getting hurt
- That students are measuring the data accurately
- That students are being consistent in how they are launching the rubber band
- To assist with finding the average launch distance for each cm mark

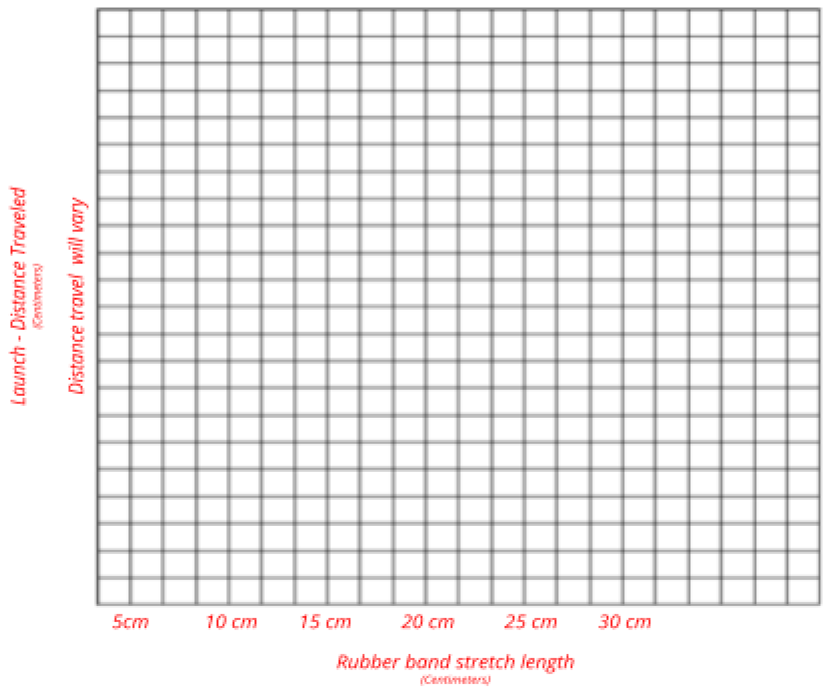
Students will have completed the investigation once they have completed a data chart for a long rubber band and a short rubber band. Once all students have completed the task, they will need to graph their data. This portion of the lesson, will most likely need to be guided. The teacher should model how to take the data from the graph and plot it on the grid. Inform students to do the following:

1. Put the stretch length (in centimeters) on the bottom (x-axis).

2. Put the launch distance (also in centimeters) on the left side (y-axis) of the graph.

3. Plot a dot for the **mid-interval distance** (how far the rubber bands flew) of each stretch length. (The mid-interval approach is being used since the concept of average has not been discussed. This approximation should be sufficient.)

4. Plot the second rubber band in a different color on the graph.



Evidence Collection

Once students have completed graphing their data, before moving onto the questions, ask students to attempt to explain what they thought was occuring during the investigations. Inform students that before they go on to explain the science behind what happened, you would like for them to do a bit more research. There are several resources available to explain potential and kinetic energy. A few resources are:

- Energy article found in the teacher resources
- http://studyjams.scholastic.com/studyjams/jams/science/matter/energy-and-matter.htm
- http://www.taylor.k12.ky.us/userfiles/1321/Classes/50347/Potential%20and%20Kinetic%20Energy%20of%20Roller%20Coasters%20Article.pdf *(There is not a need to print out the questions with this article)*

As students watch the video and/or read the text have them jot down evidence. See if students can make connections to their graph and the information in the resources provided. Have a whole class discussion with students and jot down students' thoughts, ideas, or questions.

Investigation Questions

This portion of the lesson can be done as a whole class to give students practice with reading graphs and identifying trends. An option is to have the teacher display a completed graph using a document camera or a presentation. This page can be found in the student activity handout.

1. Do the dots follow any type of pattern or trend? Explain.

2. Compare the different rubber bands. What trends or patterns did you notice?

3. What was the relationship between the amount of stretch and the launch distance?

4. What do you think this means about the relationship between potential and kinetic energy?

5. What do you think would happen if you used a different size rubber band? What would be the relationship between potential and kinetic energy with the different rubber bands?

    a. Smaller rubber band
    b. Thicker rubber band
    c. Longer rubber band

6. What patterns or relationships do you see in the data?

7. How is the potential energy in the rubber band changed to kinetic energy in this investigation?

8. How is the kinetic energy in the rubber band changed back to potential energy?

9. When did the rubber band have the most potential energy in this investigation?

10. Not all of the rubber band's potential energy was converted into kinetic energy. Where did this energy go?9

What Is Energy Definition Revision

Before going on to the formative assessment, have a short class discussion about the original definition of energy that was created at the beginning of the class. Have students reflect on what they learned through the investigation, video, and article. Ask students if there is anything they would want to change, delete, or add to their initial definition.

Inform students that they now have a working definition of energy. Students should use their definition of energy to describe the relationship between potential and kinetic energy from the different pictures presented at the very beginning of the lesson.

- Sample Student Answers For the Bus Image
  - *The bus at rest has a lot of potential energy, but no kinetic energy.*
  - *As the bus begins to move, it has lots of kinetic energy.*
  - *The faster the bus driver is moving the more kinetic energy the bus has and the more force it has if it impacts an object.*
  - *Potential energy is what is stored in the bus when it is not in motion, kinetic energy is used when the bus is in motion.*

Formative assessment

Students will complete this part alone.

Now, class, we will complete a formative assessment to explain the relationship between potential and kinetic energy. Be sure to be detailed and descriptive in your explanation. Make sure that you have labeled your diagram clearly.

Student Directions
Using one of the following examples below, explain the relationship between potential and kinetic energy. Draw a diagram to go along with your picture.

- A roller coaster starts at the top of a steep hill and speeds down
  - *The roller coaster must start at a high point to maximize on gravity and potential energy, or gravitational potential energy. This stored energy helps the roller coaster get around all the turns and loops. Anytime the roller coaster is in motion, like speeding down the steep hill, it is using kinetic energy. Potential and kinetic energy are connected in a roller coaster because the stored potential energy helps move the car around the track.*

- A stack of books is accidently knocked of the desk
  - *When a stack of books is sitting still on a desk it has potential energy. As soon as someone knocks the books over they go into motion which is kinetic energy. A book sitting at rest on a table has potential energy because if it falls off the table, motion occurs (kinetic energy). The relationship between potential and kinetic energy is that as the book's potential energy decreases its kinetic energy decreases.*

- Your bike has a flat tire and you have to push it all the way home
  - *Your bike had lots of kinetic energy until you have stopped to attempt to fix your flat tire. A common misconception about potential energy that you may observe might be, "As the bike was not in motion, it had the potential to move; it just was not moving. When the bike's kinetic energy was drained from coming to a stop after the tire was flat, the bike's potential energy increased." In reality, the bike does not have the potential energy. The kinetic energy of the bike was turned into*

heat as friction caused the bike to slow. Instead, it is energy that is stored in your body because of the food that you eat that allows you to give the bike kinetic energy. Pushing the bike home requires kinetic energy on your part to get the bike moving.

Teacher Notes

- You could allow the students to complete the demonstrations in small groups instead of a whole class demonstration.
- For the lab, to explore more results you could:
    - give each group the same size rubber band or different types of rubber bands
    - make students do the experiment twice with a different size rubber band so that they could adequately observe the relationship between potential and kinetic energy
    - You could make them graph another's group average data in a different color that had a different size rubber band than them

Citations and Resources

https://www.exploringnature.org/graphics/physical_science/energy_unit_potential_kinetic.pdf
https://www.sciencebuddies.org/science-fair-projects/project-ideas/ApMech_p017/mechanical-engineering/rubber-bands-for-energy#procedure

Rubber Band Potential and Kinetic Energy Lab
Please make sure you have enough space and DO NOT aim at anyone!

Directions: On your ruler, you will be pulling rubber bands back to five different stretch lengths: 10 centimeters (cm), 15 cm, 20 cm, 25 cm, and 30 cm. You will measure how far the rubber bands fly when released from the different stretch lengths and then write your results down in the data table.

Prediction: What do you think will happen to the rubber band at different lengths? Explain. Please use the words potential and kinetic energy in your explanation.

____
____
____
__

1. One student will need to stand on one side of the room with the materials that were handed out by the teacher. The other student will need to stand on the other side. Ensure that the student on the receiving end of the rubber band is not directly in your line of fire! The student without the materials will be responsible for marking where the rubber band lands, during each trial.

2. Put a piece of tape on the ground, this is where you will line your feet up when you test your rubber bands. This is also where you will begin measuring the distance in which your rubber bands have gone.

3. Test the distance your rubber band travels by hooking it on the front edge of the ruler, then pulling back to your first length (10 cm) on the ruler and then let go of the rubber band ensuring no one is in the direct line of the rubber band. Remember the angle and height you hold the ruler, because you will need to keep it the same for each rubber band launch.

4. Have your partner mark where the rubber band lands and measure the distance from the starting line to the location the rubber band landed. Record your measurement in your data table.

5. Repeat the steps five times for each of the centimeter marks. As you continue to test, think about whether all three trials have similar launch distances, or was there a lot of variation in how far the rubber bands flew? Average the data from these three trials to get an average distance of each of the cm marks.

6. Repeat the steps but use a different stretch length each time. For example, after you have done three trials for the 10 cm stretch length, do three trials for the 15 cm stretch length, then the three trials for the 20 cm stretch length, etc.

7. Stop after you have done three trials for the five different stretch lengths. Be sure to average your results for each stretch length. Pick a different size rubber band. Complete all the steps again.

Observations

Long Rubber Band Data Collection

Distance (cm)	**10 cm**	**15 cm**	**20 cm**	**25 cm**	**30 cm**
Trial #1					
Trial #2					
Trial #3					
Average:					

Observation #1 Reflection

1. How is this rubber band different from your first?

____

____

2. Make a prediction of what will happen. Please use the words potential and kinetic energy in your explanation.

____

____

Complete all the steps and fill out a data table for your second rubberband.

Short Rubber Band Data Collection

Distance (cm)	**10 cm**	**15 cm**	**20 cm**	**25 cm**	**30 cm**
Trial #1					
Trial #2					
Trial #3					
Average:					

Explanation

9. Make a graph of your results.
   A. Put the stretch length (in centimeters) on the bottom (x-axis)
   B. Put the launch distance (also in centimeters) on the left side (y-axis) of the graph
   C. Plot a dot for the **average launch distance** (how far the rubber bands flew) of each stretch length.
   D. Plot the second rubber band in a different color on the graph.

Summation Questions

1. Do the dots follow any type of pattern or trend? Explain.

2. Compare the different rubber bands. What trends or patterns did you notice?

3. What was the relationship between the amount of stretch and the launch distance?

4. What do you think this means about the relationship between potential and kinetic energy?

5. What do you think would happen if you used a different size rubber band? What would be the relationship between potential and kinetic energy with the different rubber bands?

    a. Smaller rubber band
    b. Thicker rubber band
    c. Longer rubber band

6. What patterns or relationships do you see in the data?

7. How is the potential energy in the rubber band changed to kinetic energy in this investigation?

8. How is the kinetic energy in the rubber band changed back to potential energy?

9. When did the rubber band have the most potential energy in this investigation?

10. Not all of the rubber band ’s potential energy was converted into kinetic energy. Where did this energy go?

Formative Assessment: Potential and Kinetic Energy

Using one of the following examples below. Explain the relationship between potential and kinetic energy. Draw a diagram to go along with your picture.

- A roller coaster starts at the top of a steep hill and speeds down
- A stack of books is accidently knocked of the desk
- Your bike has a flat tire and you have to push it all the way home

Explanation:

Diagram: Don’t forget to label it.

Energy

What do you think of when you see or hear the word energy? A toddler running around like a crazy person? Someone running a triathlon? A basketball team running up and down the court? You're right these all use energy. However, energy occurs in far more places than just athletic events and hyper children. It's probably easier to describe what energy does rather than what energy is. Energy is a property of matter, and all matter has it. Whenever a light bulb is lit, a ham is cooked in the oven, your favorite band plays a concert, a fan spins, a backpack falls to the floor, or a fire burns, you can be sure that energy in one form or another made it happen.

Kinetic energy is the energy an object has because it is moving. The greater the speed and the mass of the object, the greater its kinetic energy. For example, if a lion is chasing a hyena, the lion would have greater kinetic energy because he has more mass. A downhill skier would have a large amount of kinetic energy. In contrast, a golf ball sitting on a tee has zero kinetic energy. The golf ball would be an example of potential energy. Potential energy is the energy an object has because of its position or shape. For example, a rock sitting on the edge of a cliff has potential energy. As the rock falls, that potential energy becomes kinetic energy.

One device that uses potential and kinetic energy is the catapult. Originally catapults were designed for use during battles or wars. These days, catapults are used for a variety of reasons, from toys to even launching planes and jets from aircraft carriers that have limited runway space! The **history of the catapult** spans from ancient times well into the modern era with the basic principles of propulsion remaining the same. Designs have become more complex, but the intent is the constant – to hurl an object through the air at a target. Technically, **catapult history** begins with whatever device man first created to assist in propelling a missile at a target. For example, a slingshot operates on the same basic theory. For use in siege warfare, it is believed catapult history begins somewhere in the 300s AD. Engineers working for Phillip of Macedonia are credited with building the first ballista. This model of catapult used two wooden arms, tightly wound ropes, and a cord to assist in the hurling of deadly projectiles, such as spears, at an enemy. The ballista's use of torsion force to launch objects earned it a lasting place in the history of catapult.

Citations:
http://www.medieval-castle-siege-weapons.com/history-of-catapult.html



SCHOOL BUS

Tab page front

Label: Using Mathematics and Computational Thinking

TN Department of Education

Using Mathematics and Computational Thinking

Tennessee Academic Standards for Science

Teacher Guide for Grade 4

Standard
4.ESS1.2 Use a model to explain how the orbit of the Earth and sun cause observable patterns: a. day and night; b. changes in length and direction of shadows over a day.

Tennessee Academic Standards for Science: Page 38

Three-dimensional Learning Performance for Lesson
Students will use mathematical thinking* to measure, estimate, and analyze how the length and angle of shadows change during the day** highlighting the appropriate use and interpretation of models of the Earth-sun system.***

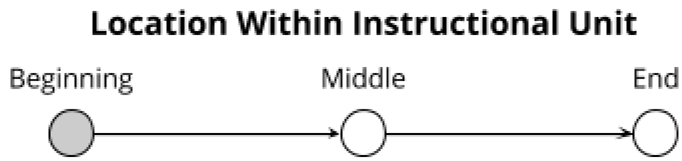
Science and Engineering Practice for Lesson
*Using Mathematical and Computational Thinking**
During the fourth grade, students are developing skill in measuring lengths and angles using rulers and protractors. They are learning to use decimals, and are expected be able to do some estimation. This lesson provides an opportunity for students to employ these mathematical skills and practices on a simple science model.

Disciplinary Core Idea for Lesson
*Earth and Space Science 1: Earth's Place in the Universe***
"Earth and the moon, sun, and planets have predictable patterns of movement."

A Framework for K–12 Science Education: Page 123

Crosscutting Concept for Lesson
*Systems and System Models****
Models help us understand complex systems. Students should be encouraged to create and use models, but also to develop an ability to assess the limitations inherent in a model. It is important that the model not be divorced from the physical system it represents. Comparison of different models representing the same physical system can help students understand the power and limitations of models.

Prior Knowledge



- Concepts that should be covered before this lesson:
    - N/A: This is a good introductory lesson on how shadows are evidence of Earth's rotation.
- This lesson covers the following portion of standard 4.ESS1.2:
    - Changes in length and direction of shadows over a day.
- The student will have already been introduced, in third grade, to the structure of the solar system. They may have knowledge about the rotation of Earth on its axis.

Materials

- For Demonstration:
    - Globe of Earth
    - Desk lamp
    - Small projection to attach to globe
- For Shadow Lab:
    - White paper, 8 ½ " x 11" (2 pieces for each student team)
    - First protractor printed on cardstock (1 per student team)
    - Second protractor printed on cardstock *OR* white paper (1 per student team)
    - Tape
    - Small flashlight with a single LED bulb (multi-LED bulbs will need the modifications discussed later in the lesson plan)
    - Small figure, like a Lego figure or a game piece, 1" to 2" high
    - Pencils
    - Rulers (metric)
    - Protractors (optional - simplified paper protractors in handout can be used)
    - Calculators
- Handouts (See Student Activity document)

Lesson Sequence and Instructional Notes

About Mathematical Reasoning in This Lesson

In this lesson, students will collect data that requires them to, with reasonable accuracy, measure the length of lines and the angles at which the lines are oriented. After students tabulate their measurements, they will use mathematical reasoning to answer questions about the data. In doing so, they will practice the mathematical skills of estimation, extrapolation from patterns, and making predictions.

The lesson is aligned with Tennessee fourth grade mathematics standards, which require students to engage in the practice of measurement (specifically lengths and angles) the use of decimals, and estimation. It also draws on mathematical skills learned In prior years, such as graphing data in bar graphs. Therefore, this lesson embeds mathematical concepts that fourth grade students are developing or have already developed.

Lesson Sequence

This lesson is built around a laboratory investigation in which students build and use models to study how shadows depend upon the angle of the light interacting with an object. The model is intended to represent shadows cast by the sun and uses a small LED flashlight to represent the sun. Students direct the light onto a small figure at specifically defined angles and collect data in order to determine the length and direction of the shadow that is cast.

In this lesson, students will be using mathematical thinking as they measure lengths and angles, estimate quantities that are between other quantities, and extend numerical patterns beyond the ones presented in the lab. They will also evaluate their laboratory model as a possible source of student misconception, and compare their laboratory model with a different model of the Earth-sun system.

- Lesson Introduction: The teacher reviews Earth's rotation on its axis, as well as how shadows are formed by objects interacting with a beam of light.
- Protractor Review: Students briefly review how to read numbers on a protractor.
- Experiments 1 and 2: Students use flashlights in differing orientations to shine light onto a small figure in order to investigate how shadow length and angle depend on the angle of light striking the figure.
- Shadow Lab Analysis: Students analyze their Shadow Lab data mathematically using skills of measurement, computation, estimation, and graphing.
- Shadow Lab Model Evaluation: Students discuss the strengths and weaknesses of the Shadow Lab as a model and compare its utility to that of a model created with a desk lamp, globe, and push pin.

Lesson Introduction

Fourth grade students are probably aware of the physical system of Earth spinning on its axis as it orbits the sun; however, this is an important concept to review at the beginning of this lesson. The teacher will want to remind students that Earth's rotation is the cause of how we perceive the sun's changing position in the sky. These concepts can be demonstrated by placing a colored dot on a globe, illuminating the globe with a desk lamp, and spinning the globe from west to east in the beam of light from the lamp. This simple model will remind students that the sun can be considered to be at a fixed point, but it appears to move across the sky due to Earth's rotation.

The teacher can also briefly demonstrate how light from the lamp interacts with objects in its path to form shadows. Students can discuss what they have observed about their own shadows when they are outside on a sunny day, and how they change in length and direction.

The teacher can show a couple of short video clips as part of the lesson introduction, such as *Following the Sun*[1] and *Shadows and the Sun*[2].

Protractor Review

Students in grade four are just learning to read a protractor to the nearest degree, so a brief review is provided at the beginning of the student handout. In this lesson, the protractor measurements are used to describe the direction of light beams and shadows. Formal mathematical definition of how the actual angles are defined is not included in the student handout. The lesson helps students practice the art of reading a protractor consistently, which is more difficult than reading a ruler because it isn't always read from left to right.

We are assigning a direction using an angle because we are, indeed, measuring an angle, although this fact is a bit hidden. Physicists do this sort of thing all the time when they assign a vector direction using an angle measure. The physicist makes the underlying and unstated assumption that the vector is one side of the angle and a line pointed in the 0^{o} or +*x* direction is the other side of the angle.

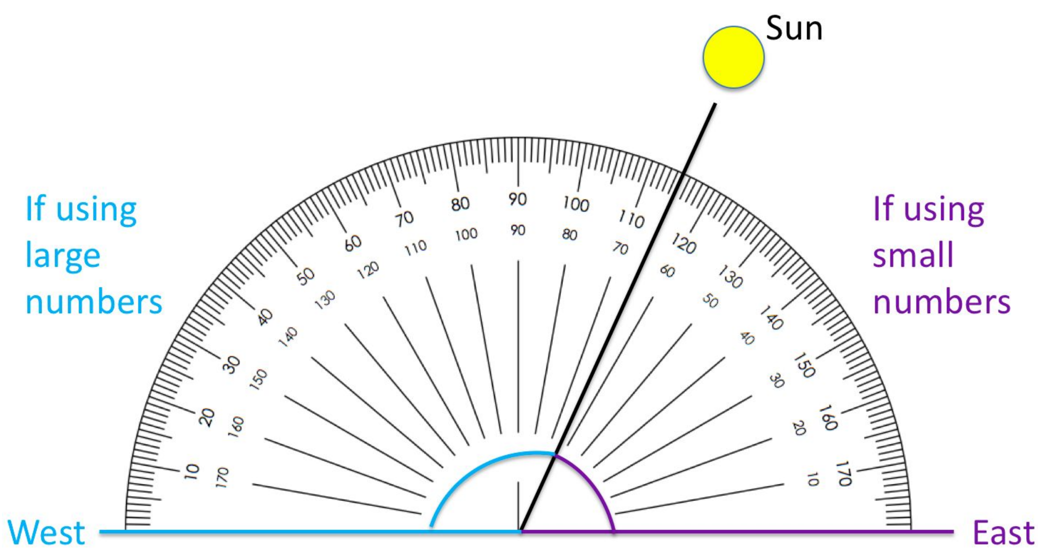
Because this is a science lesson, some of the detail of angle measure can, and probably should, be skipped. The students will be introduced formally to angles in mathematics class. This does not mean that science teachers should not try to help students understand conceptually what those protractor readings mean <u>in context</u>. The protractor reading for the direction of sunlight has a physical meaning, which can and should be articulated. Here are some questions the teacher can ask to guide student conceptual understanding and give physical relevance to the readings, along with some answers that indicate understanding:

- **When the sun is the highest, what is its angle measure?** (90^{o})
- **When the sun is just rising in the morning, what is its angle measure?** (If East is directed to the right, traditional interpretation from northern hemisphere, the sun's angle on rising is 0^{o} if the small numbers on the protractor are used. It is 180^{o} if the large numbers are used. For this reason, I prefer using the small numbers on the protractor!)
- **When the sun is setting, what is its angle measure?** (This would be 0^{o} for the small numbers and 180^{o} for the large numbers. West is to the left!)

[1] https://www.youtube.com/watch?v=1SN1BOpLZAs
[2] https://www.youtube.com/watch?v=R8dLhdV6n00

- **When the sun is midway between rising and noon, what angle would we use to describe its direction?** (This would be 45° for the small numbers and 135° for the large numbers.)

If you feel it appropriate to delve a bit deeper into the mathematics and show the students the way the angle is defined, you can use a figure similar to this one:



Experiments 1 and 2

The Student Activity Handout has instructions embedded for running both experiments. There are a few things the teacher should be aware of before embarking on this lab.

Each team will need two copies of the printable protractor at the end of the Student Activity Handout. Protractor 1 should be printed on cardstock. Protractor 2 can be printed on cardstock as well, but alternatively it can be printed on paper to save money. Both protractors need to be cut out, but differently. The protractor on cardstock must be mounted vertically at some point, so a strip of cardstock on the bottom must remain as a support. If students are cutting the protractors out, be sure to monitor this carefully.

The “small figure” can be a anything from a Lego person to a board game piece, such as a chess pawn. Ideally, the figure will be roughly cylindrical and about 1.5 or 2 inches high. It should not be very wide at the bottom, or it may obscure the shadows that are produced. If students tend to knock the figure over when running experiments, use a little tape to hold it in place. Keep in mind that it will need to be removed for data analysis.

The flashlight should be an LED light with a single beam. A small flashlight with a bright beam from a single LED is ideal. Such single-beam LEDs are found on cell phones, but cell phones have an awkward geometry and are not the best choice for the experiment. If small flashlights with multiple LEDs are used, they can easily be adapted to mimic single-beam sources. Simply cut a square of wax paper and attach it over the beam of the flashlight with a rubber band. Then, use a hole-punch to make a single hole in a piece of black construction paper, and attach this to the end of the flashlight over the waxed paper. The wax paper acts as a diffuser to blend the light from the multiple LEDs, and the hole in the black paper acts to collimate the beam.

It is important that the teacher run the entire laboratory prior to having students perform it to make sure that the choice of flashlight and figure are appropriate. This will also enable the teacher to anticipate problems students may have with data collection, measurement, and data analysis.

Student instructions for collecting data appear in the Student Activity Handout. Students should work collaboratively to collect data, ideally in groups of three. The laboratory lends itself naturally to assigning roles. One student could be responsible for aiming the flashlight, another student could insure that the flashlight is at the correct position and angle, and a third student could place a mark at the top of the shadow produced.

Shadow Lab Analysis

The Student Response Key at the end of this document contains a set of sample data and its analysis. Note that data collected by any given group of students may vary markedly, but should still exhibit the patterns in the sample data set. Exact symmetry in the data collected is not expected due to experimental error. This lab will give students an opportunity to evaluate agreement between quantities that are relatively close (within experimental error) as they compare them with quantities that are obviously much farther apart.

Evaluating the Shadow Lab Model

The lesson concludes with an analysis of the strengths and weaknesses of the Shadow Lab model, specifically that used in Experiment 2. This section offers students an opportunity to create another model that uses rotation of Earth.

Student Response Key

Note that all measurements in the key were obtained by the lesson author. Student measurements will vary depending on how the student sets up the experiment; however, the relative pattern should be similar.

Experiment 1

Light Direction (°)	Shadow Direction (°)
30	**28**
120	**117**
45	**44**

1. What can you conclude about the direction of the light and the direction of the shadow? Use the angle measurements from your data table to support your observation.

Directions should be similar for light and shadow within a given trial. A small amount of measurement error is expected, but the student should recognize the similarity.

2. Would this experiment represent a good model for how shadows are formed by light from the sun? Why or why not?

Because the sun rises high into the sky, this model is not a good one (except near the poles!)

Experiment 2

Trial	Time of Day	Light Direction (°)	Shadow Length (cm)	Shadow Direction (°)
A	8 a.m.	30°	**16.5**	**3°**
B	10 a.m.	60°	**4.3**	**15°**
C	12 p.m.	90°	**2.0**	**89°**
D	2 p.m.	120°	**4.0**	**160°**
E	4 p.m.	150°	**17.2**	**172°**

1. What would be the light direction at 6 a.m. (sunrise)?

There is a 30° change every 2 hours; therefore the light direction would be 0°.

2. At what time would you expect sunset to occur? What would be the light direction?

Any logical argument is sufficient to determine sun sets at 6 p.m. and the angle is 180°.

3. Estimate the shadow length when the light direction is 75°.

75° is between 60° and 90°. Good answers include "between 2.0 and 4.3 cm" and "3 cm."

4. Estimate the shadow direction at a time of 1 p.m.

1 p.m. is between 12 p.m. and 2 p.m. Good answers include "between 2.0 and 4.3 cm" and "3 cm."

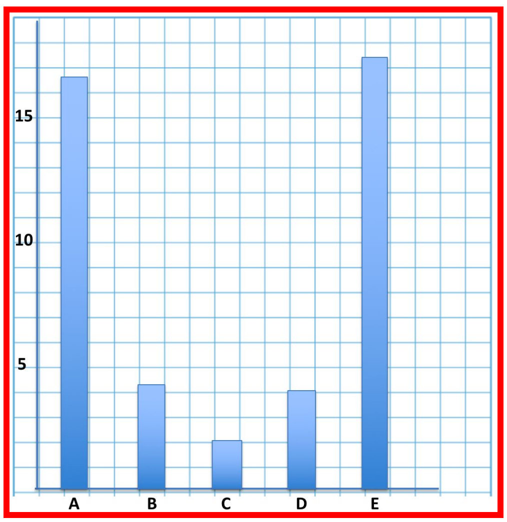
5. Is the relationship between light direction and shadow direction within a given trial the same in Experiment 1 and Experiment 2?

No, it is not. In Experiment 1, light and shadow directions in any given trial are very similar. In Experiment 2, they are different except for Trial C. (This will be very challenging for fourth graders to explain, so don't insist on an explanation.)

6. Kendra insists that shadows for Trials A and E must be the same length, and shadows for Trials B and D must be the same length. Does your data support Kendra's statement?

Students should notice that shadow length varies a lot when A, B, and C are compared. It varies a lot less when A and E are compared, or when B and D are compared.

7. On the graph paper below, draw a bar graph for length of the shadows produced by this model for the five different trials. Are the shadows changing length more rapidly at noon, or when the sun is setting? What is your evidence from the graph?



Based on the shape of the graph, the shadow length is changing fastest when the sun is setting. The height of the bar going from D to E changes a lot. The height of the bar going from B to C or from C to D changes much less. This pattern would be true for the shadow length as well.

Evaluating the Shadow Lab Model

1. Terrance says that the model in Experiment 2 is not good because it makes the sun seem to move across the sky. Do you agree with Terrance? Explain your answer.

Any logical argument will suffice. The model is good in that it represents how the motion of the sun appears on Earth and allows us to experiment with how the sun's position affects shadows. The model can indeed cause problems if taken too literally. It might cause students to believe the sun is orbiting Earth instead of the other way around.

2. Describe how you would you use the materials below to create a model that explains how the movement of Earth causes changes in shadows. The desk lamp can point a bright light in any direction, the globe can spin on the stand, and the push pin can be stuck into the globe. *Clip art is from Free Vectors.*[3]

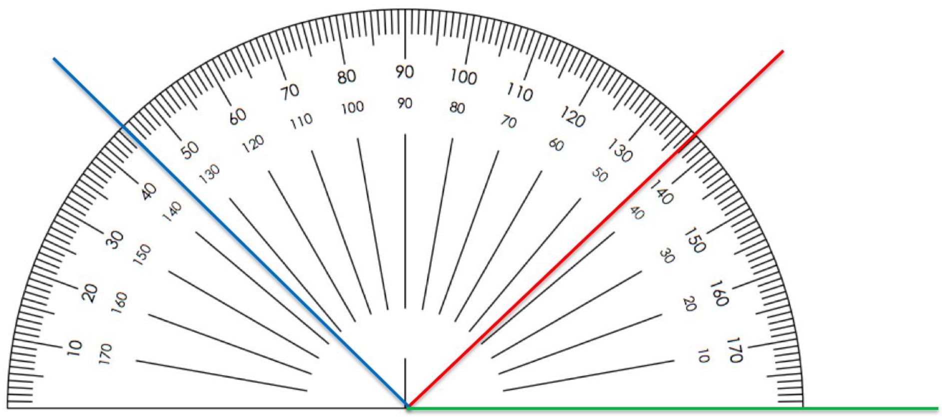
The push pin can be stuck into the globe. It will cast a shadow when the light is directed at the globe. Spinning the globe should illustrate changes in the shadow length and direction.

[3] http://all-free-download.com/free-vectors/

Shadow Lab

Protractor Review

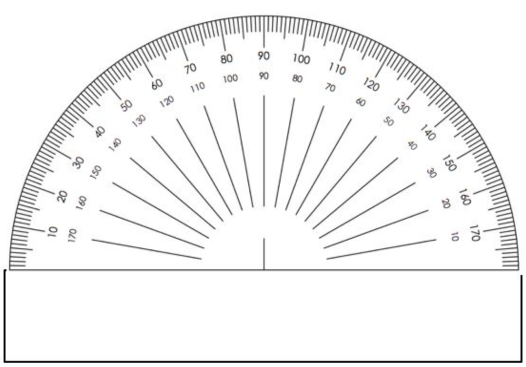
In this lab, you will use a <u>protractor</u>[1] to measure direction as an angle. The protractors have two sets of numbers, each marked in <u>degrees</u>, or $^{\circ}$. It does not matter which set of numbers you use, as long as you consistently use the same set.



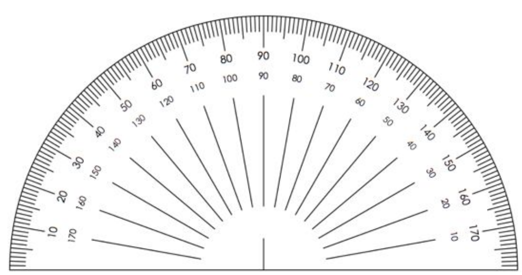
Look at the three lines in the figure above. When the larger numbers on the protractor are used, they give 45° for the blue line, 137° for the red line, and 180° for the green line. The smaller numbers give 0° for the green line, 43° for the red line, and 135° for the blue line.

Experiment 1

Cut out your two protractors as shown in the figure below:



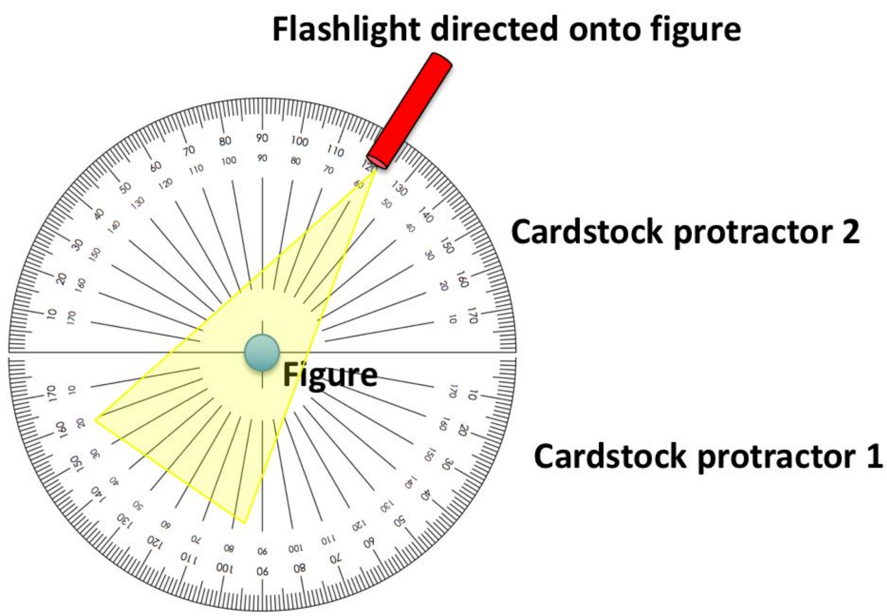
Protractor 1
Cardstock
Do not cut off extension



Protractor 2
Cardstock or Paper
Cut off extension

[1] Printable Protractor available at https://www.timvandevall.com

Arrange the protractors with the straight edges together to form a circle. Place Protractor 2 on top of Protractor 1 so all the numbers are visible. Stand your small figure in the center of the circle. Shine the flashlight from the outside edge onto the figure as shown below. Do you see the shadow?



Record the direction of the light beam and the direction of the shadow in the table below. A line through the center of the light beam or shadow defines its direction. Repeat this process for two additional light beam directions. Remember to read either the small numbers or the large numbers on the protractor, not both!

Light Direction (º)	**Shadow Direction (º)**

1. What can you conclude about the direction of the light and the direction of the shadow? Use the angle measurements from your data table to support your observation.

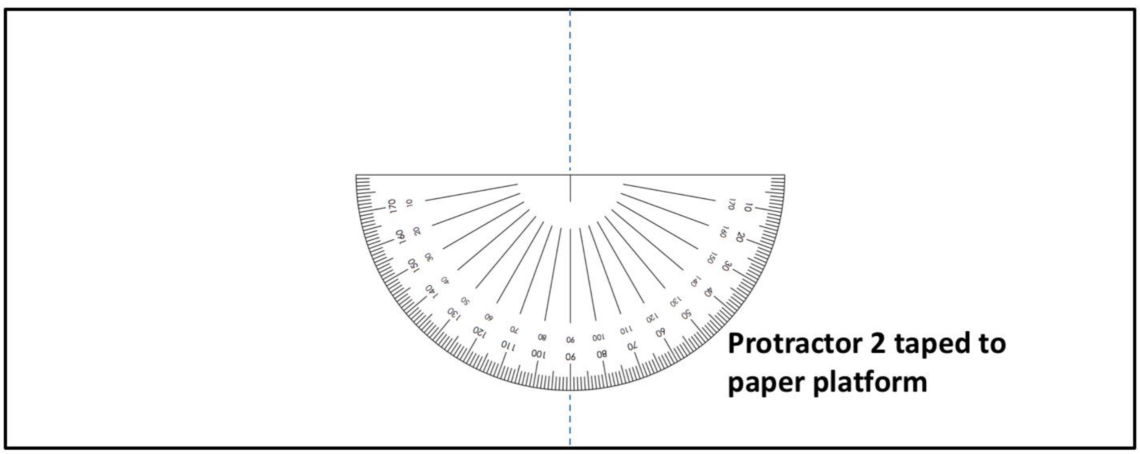
2. Would this experiment represent a good model for how shadows are formed by light from the sun? Why or why not?

Experiment 2

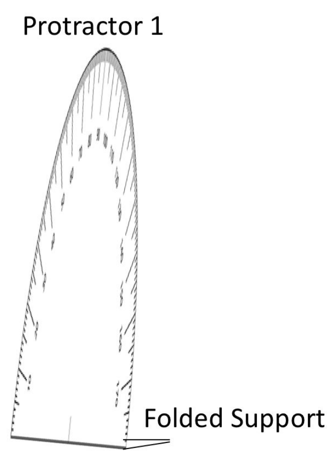
Some fourth grade students notice that the sun makes shadows on the ground that change during the day. They decide to model the motion of the sun through the sky and investigate how its position affects shadow length and direction. The students have a flashlight to represent the sun and a small figure to represent a person. They plan to shine the flashlight on the figure to form shadows.

From a local weather station, the students obtain data on the direction of the sunlight at five different times during the day. The students create a data table, and partially fill it in. Unfortunately, they are interrupted. Your job is to finish their experiment. ***Let's get started!***

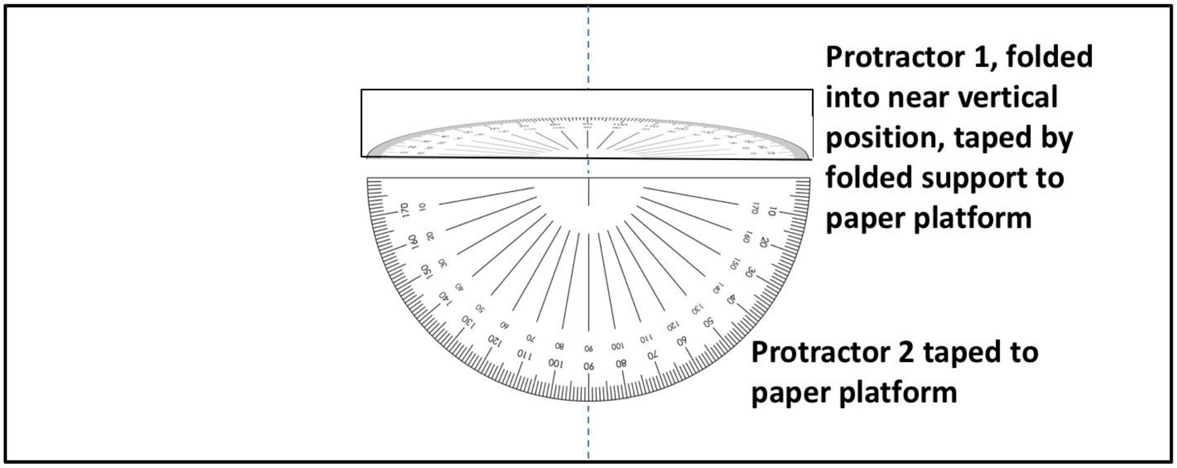
Tape together two sheets of paper to form a larger sheet as illustrated below. Then tape Protractor 2 to the paper at the position shown.



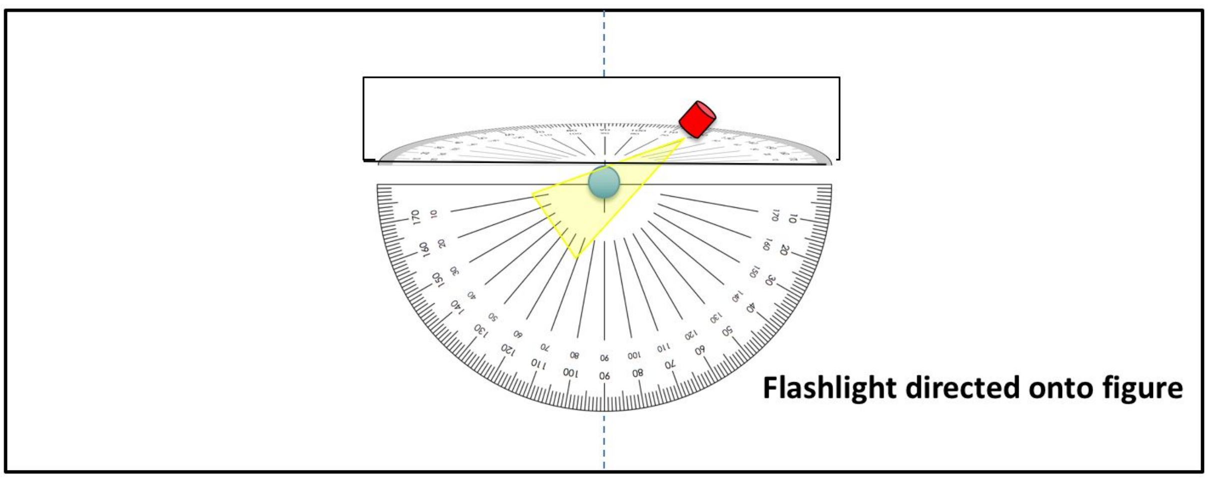
Fold Protractor 1 along its straight bottom edge so the extra cardstock forms a support. This should allow the protractor to stand almost vertically as shown.



Place Protractor 1 on the paper so its straight edge is aligned with the straight edge of Protractor 2 and the protractors are facing each other. There may be a small gap between the two protractors. Protractor 1 stands vertically and Protractor 2 lies horizontally. Tape the support of Protractor 1 to the paper to keep it still.



Stand the small figure at the location shown below. Place the flashlight along the edge of the vertical protractor and shine its light directly onto the figure. A shadow should form on the horizontal protractor. The vertical protractor gives the direction of the light. The horizontal protractor gives the direction of the shadow.



You are now ready to run the experiment. For each of the five trials, position the flashlight so it shines directly onto the small figure from the direction shown in the table. A shadow should form. On the paper or on the horizontal protractor, whichever is appropriate, use a pencil to draw a large dot to mark the part of the shadow farthest from the figure. Label the dot with a trial name (A, B, C, D, or E).

After the five trials are complete, remove the figure. Draw straight lines from where the figure was originally located (the center of the straight edge of the protractor) through each dot. Using the dots and the lines as a reference, measure the length and direction of the shadows that were formed. Record your measurements below.

Experiment 2 Data Table

Trial	Time of Day	Light Direction (º)	Shadow Length (cm)	Shadow Direction (º)
A	8 a.m.	30		
B	10 a.m.	60		
C	12 p.m.	90		
D	2 p.m.	120		
E	4 p.m.	150		

Shadow Lab Analysis

Use mathematical thinking, observation of patterns, and data from the table to answer the following questions. Explain how you arrived at each answer.

1. What would be the light direction at 6 a.m. (sunrise)?

2. At what time would you expect sunset to occur? What would be the light direction?

3. Estimate the shadow length when the light direction is 75°.

4. Estimate the shadow direction at a time of 1 p.m.

5. Is the relationship between light direction and shadow direction within a given trial the same in Experiment 1 and Experiment 2? What could cause what you observe?

6. Kendra insists that shadows for Trials A and E must be the same length, and shadows for Trials B and D must be the same length. Does your data support Kendra's statement?

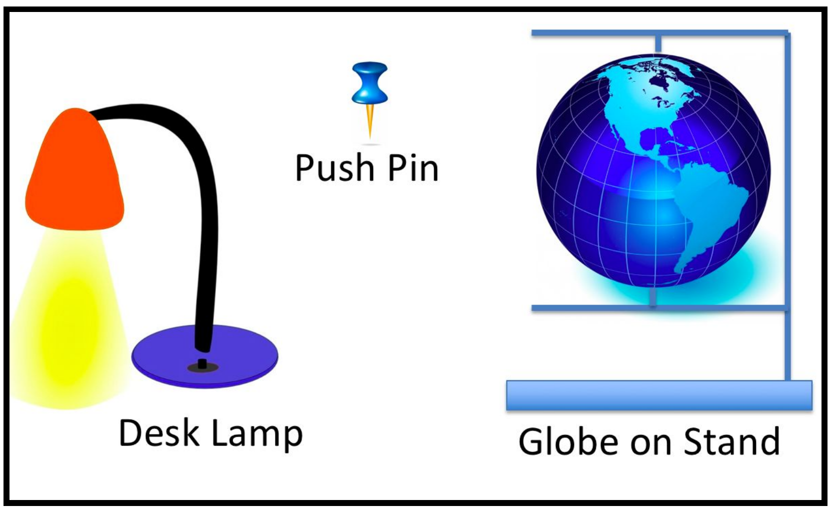
7. On the graph paper below, draw a bar graph for the length of the shadows produced by this model for the five different trials. Are the shadows changing length more rapidly at noon, or when the sun is setting? What is your evidence from the graph?

Evaluating the Shadow Lab Model

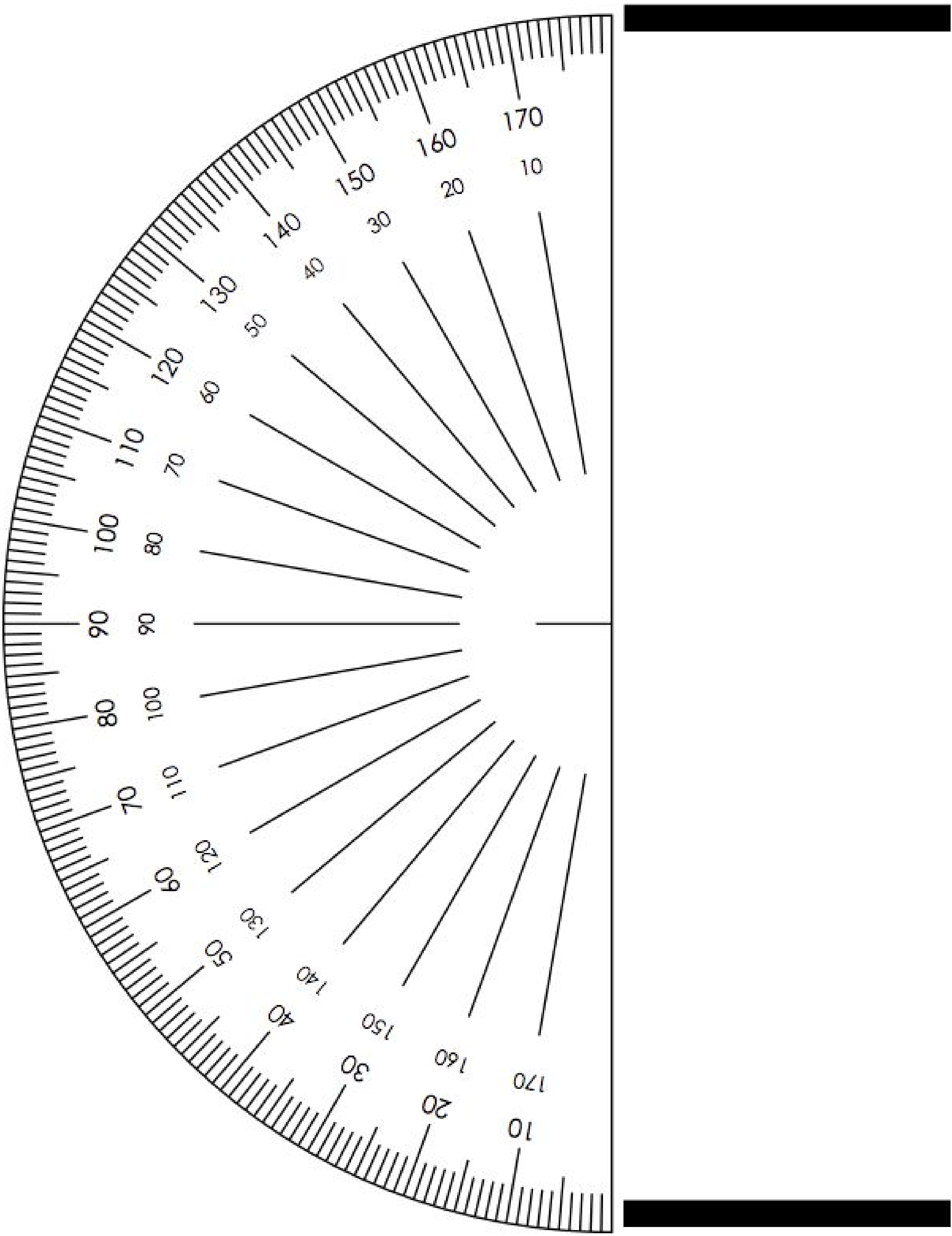
Models give us simple ways to think about complicated things. While models are valuable, it is important we not take them too literally, or they could cause us to misunderstanding the natural world.

1. Terrance says that the model in Experiment 2 is not good because it makes the sun seem to move across the sky. Do you agree with Terrance? Explain your answer.

2. Describe how you would you use the materials below to create a model that explains how the movement of Earth causes changes in shadows. The desk lamp can point a bright light in any direction, the globe can spin on the stand, and the push pin can be stuck into the globe. *Clip art is from Free Vectors.*[2]



[2] http://all-free-download.com/free-vectors/


10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170

Tab page front

Label: Constructing Explanations and Designing Solutions

TN Department of Education

Constructing Explanations and Designing Solutions

Tennessee Academic Standards for Science

Teacher Guide for Grade 4

Standard
4.ETS2.2 Determine the effectiveness of multiple solutions to a design problem given the criteria and the constraints.

Tennessee Academic Standards for Science: Page 39

Three-dimensional Learning Performance for Lesson
Students will construct explanations and design solutions* in order to determine the effectiveness of a solution to a problem** highlighting scale, proportion, and quantity within their design and testing parameters.***

Science and Engineering Practice for Lesson
*Constructing Explanations and Designing Solutions**
There is seldom a single solution to an engineering problem, but rather a number of solutions that may be evaluated based on their adherence to constraints and degrees to which they meet specified criteria. Students design a device utilizing scientific ideas as well as compare competing solutions based on constraints and criteria for success.

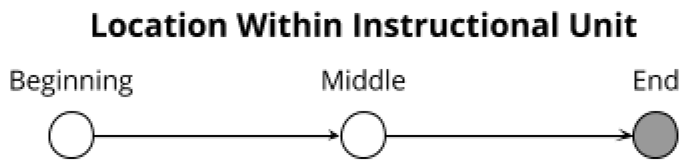
Disciplinary Core Idea for Lesson
*Engineering Design: Developing Possible Solutions***
"Research on a problem should be carried out—for example, through Internet searches, market research, or field observations—before beginning to design a solution. An often productive way to generate ideas is for people to work together to brainstorm, test, and refine possible solutions. Testing a solution involves investigating how well it performs under a range of likely conditions. Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs".

A Framework for K–12 Science Education: Page 207

Crosscutting Concept for Lesson
*Scale, Proportion, and Quantity****
It is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance. (NRC, page 84) Recipes submitted for prototype bricks require students to estimate amounts of filler material required to fill their prototype bricks. Estimation at the macroscopic scale is an imperative thinking skill in the lower grades so that students are

prepared to understand scales that are either immensely small/fast or large/slow. (Note: The thought processes utilized in this lesson parallel those required of 4.MD.A.1.)

Prior Knowledge



- Concepts that should be covered before this lesson:
    - This lesson could be built out to integrate with 4.ESS.3 to consider the effects of building on the land.
- This lesson covers all of standard 4.ETS2.2.

Materials

- Ruler precise to ⅛“
- Small paper cups
- Sand
- Glue
- Water
- Spoons
- Mixing bowl
- Non-stick cooking spray
- Bricks
- Watering can
- Flour
- Toothpicks
- Wood craft sticks
- Plaster of paris
- Clay
- Duct tape
- Masking tape
- Cardboard
- Copies of student activity
- Copies of Viewing Guide
- Books and articles on construction and building materials

Quantities of materials will vary based on the design chosen by students.

Lesson Sequence and Instructional Notes

Lesson Engagement and Questioning

Begin the lesson by re-introducing the story *The Three Little Pigs.* (Note: consider the cultural background of your class. This story may not be familiar in other cultures. This might be a good opportunity to use a telling of a similar story from a different culture.)

Ask the students to recall the three houses the pigs built and how they stood up to the "elements" (heavy wind from the Big Bad Wolf). A brief discussion of this story can be used to address: 1) The idea that building materials are suitable for different purposes and 2) to revisit the idea of criteria by having students determine the criteria of a successful pig solution.

Working with a small group, ask the students to consider properties of a brick. You may choose to use the Discussion Diamond (Stem Teaching Tool #35) more formally observe this thinking or generate an artifact. Students might say things like, "Bricks are heavy," "Bricks are red," or "Bricks are square." Students list the properties that they come up with during the brainstorm. Spend time moving throughout the classroom to gauge the types of properties being listed. Highlight student responses by sharing with the class. Further conversations can be facilitated to compel students to add things like "Bricks are waterproof" or "Bricks don't burn." To complete the discussion time, students should consider which of the properties of the bricks made them useful building materials and distinguish them from properties that are primarily aesthetic. During a discussion time, groups can consolidate their activities, re-listing in the center of their four corners sheet only the properties which affect the suitability of brick as a building material.

Problem Introduction and Research

Watch the *How It's Made: Bricks* (link listed below) and have students complete the video handout as they watch.

Group students and distribute the Explanations & Solutions_Student Activity. Direct students to read the design task and criteria. After students have had time to read, discuss the problem and expectations with students to ensure understanding. Feel free to add a time limitation to your list of constraints.

The first task of this project is for students to research brick making and the physical properties of brick components. A list of articles and books have been provided for you to choose from, but feel free to add to this list. Students are asked to read and pull out important information from three sources. Have students research construction and building materials using the book list and articles. Many of the article reference soil, rocks, and minerals used in construction and the value in each. As students are working, use questioning to prompt students to look further into these materials.

Prototype Design

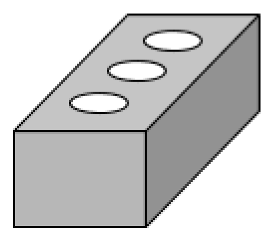
Once students are done with their research, they begin designing the recipes for their bricks. Student groups are asked to develop three recipes using their given materials. During this stage, remind students that they not only have certain materials available to them, but they also have budgetary constraints. Once they have written three recipes as a group, they will choose the best and explain their rationale.

Scale, Proportion, and Quantity (Math Connection: 4.MD.A.1)
The filler materials such as the sand and flour will fill a measuring cup in a manner similar to a liquid, allowing this to serve parallel 4.MD.A.1. As part of their prototype design, students should estimate the quantity of filler required to make their prototype brick.

Students are then prompted to refine their recipe to a shopping list with quantities. They must also explain their choices. Within the materials available, there are several choices that are similar. Students need to be clear as to why certain materials were chosen over others. Once they have clearly defined their list, students will explain their procedure for mixing and making their bricks. Before building, students will create a supply order that asks for the material, quantity, and price. Students will then total their order to make sure that they have not exceeded $15.

This is a good opportunity to reinforce measurement. Though standard scientific measurements use the metric system, students at this grade level have not been introduced to decimal systems. Math standards include the use of measurements including ⅛ of an inch and addition of fractions with like denominators. Consider cutting cardboard into 2 ½” strips to limit the amount of cutting required by students. Once students have made their bricks, allow them to cure 48 hours before testing designs.

Construction note: some materials may not dry in the allocated time. Students can speed up the drying times and reduce the materials consumed if they use non-absorbent fillers or having holes through the finished brick. (See diagram at right.)



Evaluating Designs
Ask the class to determine ways to test their designs. Remind them that the original prompt told them that it had to stand up to rain and hold heavy loads. Students will likely suggest testing how much weight it can hold. Textbooks work well for this. They will also

suggest wetting the bricks. Consider using a watering can to simulate rain. For added testing, test the ability to hold weight when wet.

Test for weight capacity while bricks are dry first. Then, test for the ability to withstand rain. When testing for rain, put the brick into a dish that will contain water and pour water over the brick using a watering can. Allow bricks to remain wet for some time before retesting for weight capacity while wet.

Once testing is complete, student groups will respond in writing describing what happened to their brick during testing. Descriptions should also include measurements of the bricks after testing. After evaluating the results, they will suggest ways to improve their design. They will then choose the best design that they saw and explain why they chose it.

Formative Assessment

This article could be used as a formative assessment. Have students read the article and identify the criteria and constraints for building the tornado safe rooms.
https://newsela.com/read/tornado-saferooms/id/160

Citations and Resources

How It's Made: Bricks https://www.youtube.com/watch?v=SbKvhHzn4hQ

http://www.understandconstruction.com/building-materials.html

https://theconstructor.org/building/types-of-building-materials-construction/699/

https://newsela.com/read/glowing-cement/id/18706

https://newsela.com/read/earthquake-test-six-story-building/id/18696

https://newsela.com/read/napa-quake/id/4973

https://newsela.com/read/roman-cement-scientists/id/32600

https://newsela.com/read/lib-roman-engineering/id/32833

Design Task: Locally produced brick

The city you live in is planning to build a new school with bricks designed locally by its own citizens.

Your task is to design a brick and the molds and forms needed to produce your brick. Each brick entered into the contest will be tested by a selection committee.

Criteria: The bricks need to be able to withstand rain storms and support the weight of a heavy load overnight. Your brick must be the standard brick size of 3 ½" D x 2 ½" H x 8" L.

Research: Before engineers begin designing, they research their problem. Read three articles or books. Document all important information from your research.

Source #1____

Source #2____

Source #3____

____

____

____

____

____

Materials:

Fillers	**Binders**	**Molds/Forms**
Sand	Glue	Toothpicks
Flour	Flour	Craft wood sticks
Clay	Plaster of paris	Plaster of paris
Toothpicks	Clay	Clay
Craft wood sticks	Water	Duct Tape
Plaster of Paris		Masking Tape
		Cardboard

Brainstorm: When engineers get ready to design a solution, they come up with as many ideas as possible. Based on what we learned about brick making and construction materials, come up with several different “recipes” for creating a brick.

Recipe #1

Filler(s)	+	Binder(s)	+	Molds/Forms(s)

Estimated amount of each filler: ______________________________________

Recipe #2

Filler(s)	+	Binder(s)	+	Molds/Forms(s)

Estimated amount of each filler: ______________________________________

Recipe #3

Filler(s)	+	Binder(s)	+	Molds/Forms(s)

Estimated amount of each filler: ______________________________________

Constraints: Budget & Materials:

You have a limited amount of money and supplies you can use to build your prototype brick to demonstrate before the selection committee. You will have a budget of $15 to purchase supplies. You may only buy from the following list of approved materials:

Material	Cost	Material	Cost
1 cup of sand	$1	1 tablespoon of Glue	$2
1 cup of Flour	$1	5 Toothpicks	$1
5 wood craft sticks	$2	1/2 cup plaster of Paris	$3
1/4 cup water	$1	1/4 cup clay	$3
1 foot of Duct Tape	$3	1 foot masking tape	$1
Cardboard to make your mold (not to be used in your final product)	$1	Your choice material (approved by teacher)	$5

Constraints: Budget Evaluation:

Recipe 1 Cost:

Material	*Number of Portions*	*Cost of each portion*	*Cost for material*
		Total Cost:	

Recipe 2 Cost:

Material	*Number of Portions*	*Cost of each portion*	*Cost for material*
		Total Cost:	

Recipe 3 Cost:

Material	*Number of Portions*	*Cost of each portion*	*Cost for material*
		Total Cost:	

Do your recipes fall within budget constraints? Use evidence from your table above.

Recipe 1:

____

____

Recipe 2:

____

____

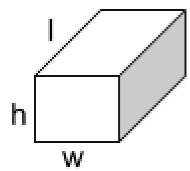
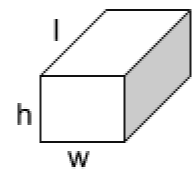
Recipe 3:

Explain your procedure for mixing your ingredients, making your mold, and projected time to cure.

Build: Purchase the materials and build your brick prototype.

Test you designs. Each brick will be tested to see how it withstands a rain storm and a heavy load.

Brick Tests:
Use the table below to organize the results from the tests you performed. Record the dimensions of your brick to ⅛ of an inch, and make a list of words that describe your brick before and after your test.

Pre-test observations	Post-test observations
Measurements  Length (l): ________Width (w): __________ Height (h):____________	Measurements  Length (l): ________Width (w): __________ Height (h):____________
Appearance:	Appearance:

- Use evidence to explain to the selection committee how your design met the selection criteria and the constraints.

____

____

____

____

____

Fill in the columns while viewing *How It's Made: Bricks.*

Steps of the Brick Making Process	Materials for Brick Making	Advantages of Brick

Tab page front

Label: Engaging in Argument from Evidence

TN Department of Education

Engaging in Argument from Evidence

Tennessee Academic Standards for Science

Teacher Guide for Grade 4

Standard
4.PS4.1 Use a model of a simple wave to explain regular patterns of amplitude, wavelength, and direction.

Tennessee Academic Standards for Science: Page 37

Three-dimensional Learning Performance for Lesson
Students will construct an argument from evidence* in order to show that wave interference affects wave properties**, highlighting constructive and destructive wave interference patterns.***

Science and Engineering Practice for Lesson
*Engaging in Argument from Evidence**
The goal of this three-dimensional learning performance is for students to develop a scientific argument to explain how noise-cancelling headphones work. Students will investigate wave interference (constructive and destructive) through a series of activities in order to obtain data to use as evidence. Students will also examine text to obtain further evidence. Using these sources of data, students will then answer the original question from the proposed phenomena: How do noise-cancelling headphones work?

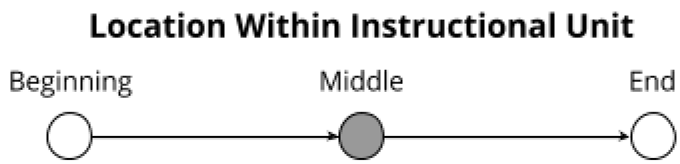
Disciplinary Core Idea for Lesson
*Physical Science: Waves and their Application in Technologies for Information Transfer***
Waves of the same type can differ in amplitude and wavelength. Waves can add or cancel one another as they cross, depending on their relative phase, but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.)

A Framework for K–12 Science Education: Page 132

Crosscutting Concept for Lesson
*Cause and Effect: Mechanism and Explanation****
As students explore each investigation, they discover the relationship between the initial phase of the waves (cause) and the resulting interference wave pattern – either constructive or destructive (effect). Students also discover that after the interference, the waves each return to their original forms. Finally, students use the data from the investigations to explain the cause and effect relationship of noise-cancelling headphones.

“Headphones like this have a small microphone built into their case. The microphone constantly samples the background noise and feeds it to an electronic circuit inside the headphone case. The circuit inverts (reverses) the noise and plays it into the loudspeaker that covers your ear. The idea is that the noise you would normally hear is canceled out by the inverted noise—so all that's left (and all you hear) is near silence or the music you want to listen to.” http://www.explainthatstuff.com/noisecancellingheadphones.html
So, in simple terms, the headphones create destructive interference to “cancel out” the sound.

Prior Knowledge



- Concepts that should be covered before this lesson:
    - Basic wave properties of amplitude and wavelength
    - An understanding that waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks)
    - Comparison of longitudinal and transverse waves
- This lesson covers portions of standard 4.PS4.1:
    - The focus of this lesson is on the “direction” portion of the standard.
    - Students examine both constructive and destructive wave interference and the resultant effect on wave properties and direction.

Materials

- A pair of noise-cancelling headphones or earbuds (if possible)
- Slinkys
- Long jump ropes
- Teacher wave model (wooden skewers, duct tape, and gummy bears)
- This should be constructed prior to the lesson and can be used with the learning performance for 4.PS4.1 addressing the practice of constructing models.
- Textbook passage, video, or other resource with information on wave properties and interference. A sample text is included in this activity.

Lesson Sequence and Instructional Notes

Have students read the introductory text on the student activity sheet. If possible, have a pair of noise-cancelling headphones or earbuds available for students to try. A video showing different headphones (but NOT describing how they work) could also be shown, but is not necessary.

Example: https://www.youtube.com/watch?v=KvjeIYfFRKY

Explain to students that the goal for this activity is to develop a claim about how noise-cancelling headphones work, identify evidence that supports that claim, and describe the scientific principles about each piece of evidence.

In simple terms, the activities that students will complete in class will help them understand how the headphones work and the science behind it.

Have students complete steps one and two on the student activity sheet, which asks them to predict what happens when two waves meet and cross each other. Sound waves are actually longitudinal waves, but are often represented as transverse waves for easier discussion. For this activity, the interference of only transverse waves will be represented. Notice that the predictions include what happens both at the point that the two waves "cross" as well as what happens AFTER the waves have crossed and continue past each other.

Students can share predictions with each other and/or the teacher can display some of these for the class to discuss. One suggestion is to use the "Share-Trade" Activity found at http://stemteachingtools.org/sp/talk-flowchart:

- When you give students an open-ended question, share-trade can help students refine their ideas and their language over time.
    - Each student writes their individual thoughts.
    - Students stand up with their ideas on paper and move around the room.
    - Each student finds someone they don't know very well and forms a partnership with them. To form a partnership, students must high five.
    - With their partners, students share their ideas and trade papers.
    - Each student is now responsible for sharing the ideas of the person they just spoke with, even if they don't agree with those ideas. This isn't a time for them to critique their partners' ideas.
    - Students form partnerships three or four times so they see and explain multiple ideas.
    - Students return to their seats and write a final explanation or idea.

Ask students to think about how they could determine if their predictions are correct. Encourage students to examine the available materials in the room (ropes, slinkys, etc.) to prompt their thinking. The idea is for them to figure out how to model "two waves meeting."

Students should complete the data table by making observations and explanations of the resultant interference patterns. Teachers may choose to have students complete the activities independently or with direct teacher guidance, depending on the needs of the classroom. It is helpful to have a whole class discussion after each activity in order to "share out" observations.

Rope

- Have two students sit on the floor, each holding one end of the rope.
- One student should start a wave at his/her end.
- The second student should immediately start a wave from his/her end ON THE SAME SIDE OF THE ROPE. This is referred to as being "in phase."
- Students should observe that the amplitude of the two waves combine when the waves cross to momentarily create one wave with a larger amplitude. The waves then continue on past each other and return to their original positions. This video provides additional help: https://www.youtube.com/watch?v=ypcX1LdmMPM.

The term "constructive interference" can be introduced at this point. It refers to the type of interference that occurs at any point along the medium where the two interfering waves have a displacement in the same direction. In simple terms, the amplitude of the wave will "get bigger."

Students should now repeat the activity except start the waves from OPPOSITE sides of the rope. Students should observe that as the two waves cross, the amplitudes "cancel each other out". This video demonstrates the process: https://www.youtube.com/watch?v=J4qFPComzoo. The term "destructive interference" can be introduced at this point.

Destructive interference refers to the interference of two waves where the two waves have displacement in opposite directions. In simple terms, the two waves will "cancel each other out". If the displacement of each wave is exactly equal, then the rope will be a straight line at the moment the waves cross each other.

Slinkys

- Students can repeat the investigation above using slinkys. Some students may ask if longitudinal waves can also demonstrate interference. The answer is that they most certainly do – sound is actually a longitudinal wave – however, it is harder to show that with ropes and/or slinkys.
- These videos demonstrate the process:
  - https://www.youtube.com/watch?v=SCtf-z4t9L8
  - https://www.youtube.com/watch?v=P_rK66GFeI4
- Note the addition of small objects on either side of the slinky that show the amplitude increasing and knocking over the objects.

Students can repeat the investigation using the wave model used as a demonstration in lesson Models_4.PS4.1. This model uses wooden skewers, duct tape, and gummy bears to create a wave model that can easily be used by students to demonstrate wave interference patterns.

- Instructions to create this model can be found here:
    - https://www.flinnsci.com/api/library/Download/302eb8450d264a99b0e72b14bcff9994
    - https://www.youtube.com/watch?v=UWGhMttIUZw&t=12s

Music/Sounds[1]

- Have two students stand on opposite sides of the classroom.
- Each student should have an object to make a simple sound: beating a can, whistling, ringing a bell, etc.
- The rest of the class should stand in the middle of the classroom.
- Have the two students begin making sounds. The idea here is that the students in the middle of the classroom can hear BOTH sounds. The sounds are passing each other while going in different directions, but the sounds do not get mixed up. This demonstrates that waves emerge unaffected by each other.

Animations

- The following animations are useful in helping students to see:
    - Constructive interference
    - Destructive interference
    - The concept that waves emerge unaffected after crossing each other
- Students may view these individually or as a whole class, in whatever manner is most appropriate.

http://falstad.com/ripple/index.html - This video shows the interference patterns of two water waves. Change the example to “two sources” to see the patterns. Dark areas indicate areas of constructive interference. Light areas of destructive interference appear as bands.

http://zonalandeducation.com/mstm/physics/waves/interference/waveInterference2/WaveInterference2.html This is a simple animation showing wave interference.

http://ophysics.com/w2.html This is a simple animation showing wave interference.

http://physics.bu.edu/~duffy/HTML5/interference.html This animation is easy to pause to show constructive and destructive interference patterns.

[1] *A Framework for K-12 Science Education* pg. 132

In addition to hands-on demonstrations and computer simulations, students can also access text and/or videos to help with understanding. A space is included on the student activity sheet for students to write additional evidence from text sources, including textbooks.

Students will use the evidence from the investigations, including text and/or video sources, to complete a “claim, evidence, reasoning” section. This section begins with the question, “What happens when two waves collide or interfere with each other?” Sentence prompts are included for support. Teachers may choose to do this as a whole class activity depending on the needs of their students.

Students end the activity by referring back to the original phenomenon: How do noise-cancelling headphones work? Students should develop a claim about how noise-cancelling headphones work, identify evidence that supports that claim, and describe the scientific principles about each piece of evidence.

Allow students appropriate time to develop their arguments. An example strategy that allows students to share their arguments with each other can be found at http://stemteachingtools.org/sp/talk-flowchart. This strategy is called “All Class Science Talk”.

Finally, allow time to affirm student connections of the scientific principles behind noise-cancelling headphones. The following link contains an easy activity that allows students to SEE how the headphones actually work! Scroll down to use the activity:

http://www.explainthatstuff.com/noisecancellingheadphones.html

Short video explanations can be found at the following links:
https://www.youtube.com/watch?v=HOdEvhEjO2I
https://www.youtube.com/watch?v=VTx4JgYsW5s

Citations and Resources

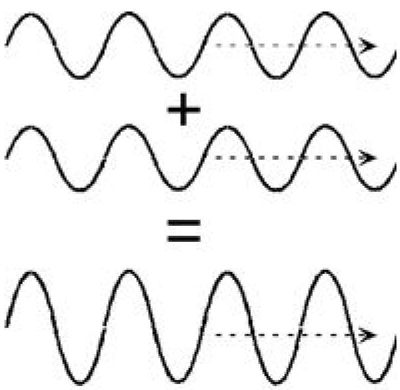
http://falstad.com/ripple/index.html
https://www.youtube.com/watch?v=4ujcWDyXdBI
http://zonalandeducation.com/mstm/physics/waves/interference/waveInterference2/WaveInterference2.html
http://ophysics.com/w2.html
http://physics.bu.edu/~duffy/HTML5/interference.htm
https://www.youtube.com/watch?v=SCtf-z4t9L8
https://www.youtube.com/watch?v=P_rK66GFeI4
https://academo.org/demos/virtual-oscilloscope/
http://www.explainthatstuff.com/noisecancellingheadphones.html
http://www.mathalicious.com/lessons/the-sound-of-silence
https://www.youtube.com/watch?v=c5JfH-rCC_A
https://www.youtube.com/watch?v=HOdEvhEjO2I (Science Explanation SciShow)
https://www.youtube.com/watch?v=VTx4JgYsW5s
http://phenomscience.weebly.com/blog/phenomena-based-engagement-to-build-concepts-part-3-summary-tables
https://www.sciencelearn.org.nz/resources/121-behaviour-of-waves

ClipArt:
http://www.alanpedia.com/physics_waves/waves.html
http://slideplayer.com/7461620/24/images/50/Interference.jpg

Catch the Wave!

When two waves travelling in different directions meet, they combine their energies and form interference patterns. This can result in regions of very high waves when they add up (constructive interference) alternating with regions of diminished or no waves when they cancel out (destructive interference).

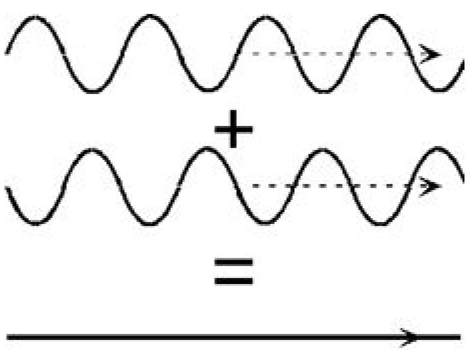
Constructive Interference:



www.UConnPhysics.edu

The figure above shows one example of what can happen when two waves "meet." If the crest of one wave lines up with the crest of a second wave, the energy from the two waves will combine. The amplitude of the new wave will be the sum of the two original amplitudes. You can think of constructive interference as waves "helping each other" give a stronger result or combining energy.

Destructive Interference:



www.UConnPhysics.edu

The figure above also shows two waves "meeting." When the crest of one wave lines up with the trough of a second wave, the amplitude of the first wave cancels out the amplitude of the second wave. If the amplitude and trough are exactly equal, the original waves will seem to be smaller or even destroyed. Remember that in both cases, the waves continue unchanged AFTER the cross-over. It's only when the waves meet or overlap that interference occurs.

Interference is important for surfers because it affects the size of surf waves. When two sets of swells with similar frequencies interact, they interfere with each other and form groups. Within the groups, interference means that the wave height will vary. Surfers can tell from the interference pattern which wave will be the biggest (and the best to surf!), for example, every seventh wave.

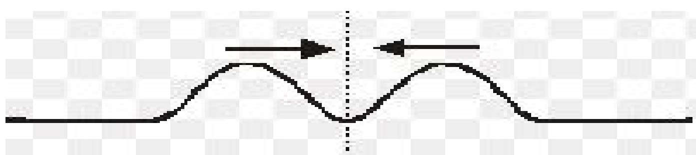
Text Retrieved From: https://www.sciencelearn.org.nz/resources/121-behaviour-of-waves

Name ___________________________________

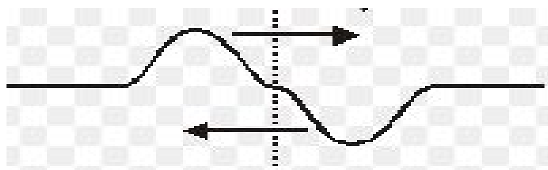
While riding on a bus with your friend, you notice the person in front of you listening to music. Because the sound of the bus engine is so loud, the person has turned up the volume of the music and you can hear every note! Your friend suggests that all of you need some noise-canceling headphones.

Noise-canceling headphones are amazing, your friend insists. They don't just block the sounds from coming into your ears, but actively destroy them. They actually make more noise so that you end up hearing less noise. But how do noise canceling headphones work?

1. When two waves meet each other, it is known as wave interference. In the space below, predict what will happen when two transverse waves meet each other.

Before Waves Interfere 
During Interference of Waves
After Waves Interfere

2. Would it make a difference if the waves start at opposite positions? Make a prediction about what would happen in this case.

Before Waves Interfere 
During Interference of Waves
After Waves Interfere

3. How can we gather evidence about wave interference to find out if our predictions are correct?

Activity	Observation	Why? What cause and effect relationship is there? What patterns do you see?
Rope		
Slinky		
Teacher Model		
Sounds/Music		
Animations		

Text Evidence:

5. Scientific Question: What happens when two waves collide or interfere with each other?

A. Claim: When two waves collide, if both waves are on the same side, then

____

Evidence:

Reasoning:

B. Claim: When two waves collide, if the waves are on opposite sides, then

____

Evidence:

Reasoning:

C. Claim: When two waves collide, <u>after</u> the collision

____

Evidence:

Reasoning:

6. How do you think noise-cancelling headphones work? Based on the evidence from the investigations and text, develop an argument to explain how noise-cancelling headphones “make more noise so that you end up hearing less noise.” Develop a claim about how noise-cancelling headphones work, identify evidence that supports that claim, and describe the scientific principles about each piece of evidence.

Claim:

Evidence:

Reasoning:

Name ______________________________

While riding on a bus with your friend, you notice the person in front of you listening to music. Because the sound of the bus engine is so loud, the person has turned up the volume of the music and you can hear every note! Your friend suggests that all of you need some noise-canceling headphones.

Noise-canceling headphones are amazing, your friend insists. They don't just block the sounds from coming into your ears, but actively destroy them. They actually make more noise so that you end up hearing less noise. But how do noise canceling headphones work?

3. How can we gather evidence about wave interference to find out if our predictions are correct?

Activity	Observation	Why? What cause and effect relationship is there? What pattern do you see?
Rope	When waves are started from opposite sides of the rope on the SAME side, the wave gets bigger right at the point of interference. After they cross, the waves continue on and look the same as they started. When the waves are started on opposite sides of the rope, it looks like the wave gets smaller right at the point that the waves cross each other. Sometimes, it looks as if the	When the two waves overlap, their amplitudes are "added together." Their energy combines to produce a wave with a bigger amplitude. When the two waves overlap from opposite sides of the rope, the displacement from the center is in opposite directions. When they cross, the waves "cancel" each other out. In both cases, after they cross, the waves continue in the same direction and look the same as when they started.

	wave disappears because the rope is flat for a second. However, after they cross, the waves continue on and look the same as they started.	

Activity	Observation	Why? What cause and effect relationship is there? What pattern do you see?
Slinky	Similar to above	Similar to above
Teacher Model	Similar to above	Similar to above
Sounds/Music	We can hear both sounds or voices. Neither of the voices disappear.	Sound is carried by waves. Even though the sound waves are crossing in the middle of the room, we can hear both sounds. This shows that the waves might interfere but still keep moving and continue to carry the sound across the room.
Animation	Similar to above	Similar to above

Text Evidence:

Constructive interference is when two waves “help each other” and add their energy together right at the point that they cross. After they cross, they continue in the same direction and their amplitudes return to the original amplitude that they had before they interfered.

Destructive interference happens when two waves cross each other and aren’t “lined up.” The crest of one wave lines up with the trough of another wave. This makes the waves “cancel” each other out right at the point when they cross.

Surfers know about wave interference and take advantage of it to find the “biggest” wave with the most energy.

5. Scientific Question: What happens when two waves collide or interfere with each other?

A. Claim:

When two waves collide, if both waves are on the same side, then the crests of the two waves will line up and overlap, making a bigger wave. After they cross, the waves go back to how they looked when they started. They also just keep going in the same direction.

Evidence:

When we used the rope and the slinky, we started waves from opposite direction but on the same side. We could see that right at the time where the waves came together, the amplitude of the wave got bigger.

The animations that we looked at also showed the same thing. We could see that the waves became bigger just for a second, but then went back to their original form. The waves kept moving in the same direction. They didn't stop moving. The text describes how surfers use this fact to find the biggest waves to surf.

Reasoning:

When two waves interfere and they "line up" so that their crests are lined up, the energy of the two waves add together. When the energy adds together, it makes a bigger wave with larger amplitude. When the waves finish crossing, they each go back to having their original amount of energy. They also keep moving in the same direction.

B. Claim:

When two waves collide, if the waves are on opposite sides, then the crest of one wave will line up with the trough of the second wave. At the point that the two waves meet, the wave will look smaller or even look like it disappears for a second.

Evidence:

Similar to above but should demonstrate understanding of destructive interference.

Reasoning:

Similar to above but should demonstrate understanding of destructive interference.

C. Claim:

When two waves collide, after the collision the waves continue in the same direction.

Evidence:

Several students stood in the middle of the room. We had students make sound from either end of the room. We know the sound waves crossed each other, but we could still hear all the sound.

Reasoning:

When waves interfere, they are affected by whether it is constructive or destructive interference. However, after the waves cross, they continue to move in the same direction and with the same energy that they had before they interfered.

6. How do you think noise-cancelling headphones work? Based on the evidence from the investigations and text, develop an argument to explain how noise-cancelling headphones "make more noise so that you end up hearing less noise". Develop a claim about how noise-cancelling headphones work, identify evidence that supports that claim, and describe the scientific principles about each piece of evidence.

Claim: Noise-cancelling headphones work by producing sound waves that interfere with a second sound and cancel it out.

Evidence:

Sound travels in the form of a wave that carries energy. If two waves cross each other, it is called wave interference.

When we used the rope and the slinkys in class, we observed that when the waves started on opposite sides, they cancelled each other out when they met. This is called destructive interference. It means that the trough of one wave is lining up with the crest of the second wave. If the two waves are exactly the same amplitude, it totally cancels them out. Even when one wave was bigger, it still made a smaller wave when they met.

The animations also showed that if you get the waves to line up in opposite directions, they cancel each other. So, the headphones must have a way to hear outside noise and then make "more noise" that travels in waves that cause destructive interference with the first sound.

When we did the activity with two students making sound on opposite sides of the room, we could still hear both sounds, even though we were standing in the middle. That means that the sound waves keep moving even after they cross. For the noise-cancelling headphones to work, they would have to keep making a sound wave that lines up opposite of the first sound.

Reasoning:

So, the noise-cancelling headphones work because of the destructive interference. The headphones listen to the outside noise and then produce a sound wave that has an opposite amplitude. When they meet, they cancel each other out and you don't hear anything!

Tab page front

Label: Obtaining, Evaluating, and Communicating Information

Obtaining, Evaluating, and Communicating Information

Tennessee Academic Standards for Science

Teacher Guide for Grade 4

Standard
4.LS2.3 Using information about the roles of organisms (producers, consumers, decomposers), evaluate how those roles in food chains are interconnected in a food web, and communicate how the organisms are continuously able to meet their needs in a stable food web.

Tennessee Academic Standards for Science: Page 37

Three-dimensional Learning Performance for Lesson
Students will obtain, evaluate, and communicate information[*] in order to show that the different roles of organisms are interconnected in a food web[**] highlighting the inside or outside of the system.[***]

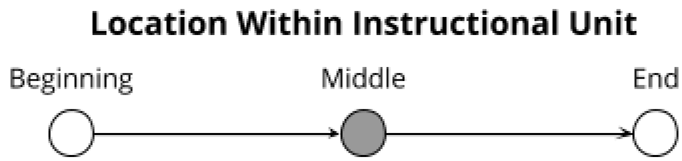
Science and Engineering Practice for Lesson
Obtaining, Evaluating, and Communicating Information[*]
The goal of this three-dimensional learning performance is for students to obtain, evaluate, and communicate information about organisms. The students will focus on the roles of producers, consumers, and decomposers as they evaluate how they are interconnected in a simple food chain and how they are connected to a food web.

Disciplinary Core Idea for Lesson
Life Science 3: Ecosystems: Interactions, Energy and Dynamics[**]
Ecosystems are complex, interactive systems that include both biological communities (biotic) and physical (abiotic) components of the environment. As with individual organisms, a hierarchical structure exists: groups of the same organisms (species) form populations, different populations interact to form communities, communities live within an ecosystem, and all of the ecosystems on Earth make up the biosphere. Interactions between organisms may be predatory, competitive, or mutually beneficial.

A Framework for K–12 Science Education: Pages 150-152

Crosscutting Concept for Lesson
Energy and Matter[***]
Although energy is a concept taught beginning in middle school, it is an underlying concept in the understanding of a food web. It is imperative that teachers do not teach misconceptions, but explain the role that energy plays when discussing food webs. As a subconcept of the systems and system models crosscutting concept, it is essential to note that the matter used to build living organisms is brought into the system by producers.

Prior Knowledge



- Concepts that should be covered before this lesson:
    - The role of producer, consumer, decomposer in a food chain
    - Basic examples of organisms in the different categories of herbivore, omnivore, and carnivore
    - That the sun is the major source of energy
    - A simple food chain such as plants use sunlight to get energy, a rabbit eats the plant, and then a leopard eats a rabbit
    - The dynamics of a food web
- This lesson covers a portion of 4.LS2.3
    - How food chains and food webs are interconnected
    - Reinforces the flow of energy through a food web
- After this lesson
    - Further instruction on how to communicate how the organisms are continuously able to meet their needs in a stable food web

Materials

- Yarn
- Prints of different pictures of animals in a food chain
- Large sheets of construction paper

Lesson Sequence and Instructional Notes

Engage/Review

Pose the following questions to the students:

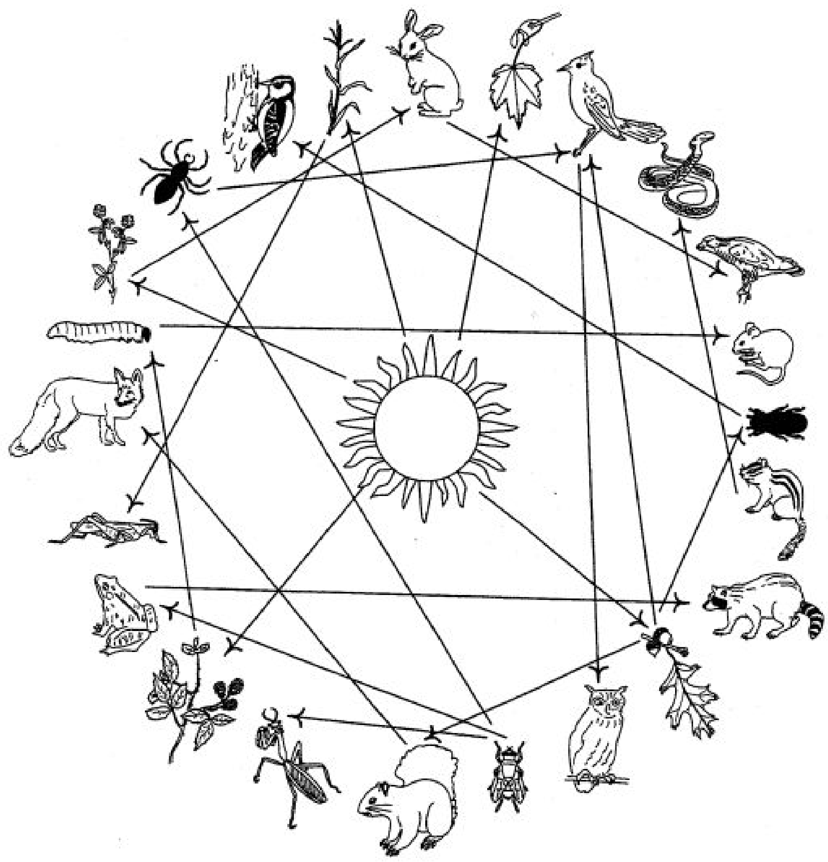
1. What is the difference between a food chain and a food web?
2. What are some key things that you would see in a food chain/food web?

Food Chain/Food Web Simulation

- The class will make a large food web outside with yarn. The purpose of this activity is to model a food web and to begin to identify connections between food chains.

Preparation

- Prepare several different cards with animals in a food web. Cards should include name and a small picture. There is an additional handout of sample cards that can be cut and laminated for this activity. There should be enough organisms that every student gets one, and one student should represent the sun.
- Make sure that you have a large ball of yarn.
- These cards can also be made into necklaces by attaching a loop of yarn and the students can wear them during the activity (and the other students can see the picture).
- You will need to go outside (weather permitting) or to a larger indoor space on campus since they will need to make a large circle.
- Distribute the organism cards before students get into the circle. The student who is the sun stands at the center of the circle.
- Students will be making different food chains outside such as: the sun tossing the yarn to a green plant, the green plant tossing the yarn to a deer, the deer tossing the yarn to a wolf. At the wolf the teacher should cut the yarn and begin a new food chain. An example of what could happen from after the first food chain is complete.
- To begin a new food chain, the teacher gives the yarn back to the sun and they start the process all over again. For example, tossing the yarn to a different green plant, this green plant tossing it to a rabbit, and the the rabbit tossing it to a cougar. At the cougar, the teacher would cut the yarn and then allow the students to start another food chain. Each food chain should start with the sun.
- The activity should end when each student has at least one piece of yarn.
- The teacher should document the food chain, so that students can discuss it when they are back in the classroom. Here is an example of a sample final web.
- To document the food web, it would be a great idea to organize the students by card or by name, so that it is easy to draw the connections as they make the web.



Directions

1. Explain to students that they are now going to make a giant food web. They will need space to complete this activity because we will be lightly tossing a ball of yarn.
2. Explain to them that the ball of yarn represents sunbeams, or energy from the sun. The student representing the sun should hold the end of the yarn tightly and toss the ball to someone who can use that energy (a green plant).
3. When the student representing the green plant catches the ball of yarn, he or she should hold a piece of the yarn and throw the ball to someone else who could use the energy.
4. Explain to students that for this activity's purpose, we will end each food chain with an animal that has minimum of a few predators. For example, humans, bears, raccoons, etc. are omnivores and can end a food chain, or they could be eaten by a carnivore. Remind the students to keep holding onto the yarn and that they might be holding more than one strand during this activity.

Probing Questions During the Model

Ask the following questions (student sample answers are italicized):

1. What does the ball of yarn represent? *Energy*

2. Why does the food web always begin with the sun?
3. Why do we have a rule that the sun must pass the yarn to the plant first?
4. Who in the circle could I give my energy to? Who might eat me?
5. Who in the circle could give me energy? Whom could I eat?
6. How can all these other plants and animals get the energy they need? *Through different food chains*
7. Why did you throw the yarn to ____________? Explain.
8. In the middle of the activity, ask the students what would happen if all the green plants died out? *Nothing else in the food web would survive*.

Summation Questions After the model

1. Have we made food chains? *Yes, lots of them!*
2. What do all of our food chains together look like? *A food web.*
3. What is the difference between a food chain and food web? *A food web is made up of several food chains. A web is more complicated than a chain because it has connections among the chains.*
4. Who is holding the most pieces of yarn? *The sun.* Why? *Because each food chain starts with the sun.*
5. Who else is part of many food chains? *Green plants*
6. Why do all food chains start with the sun? *The sun provides plants with energy that they can convert into food. Without this energy source, plants would not be able to live and survive, hence hindering the rest of the food chain*
7. In what ways were our modeling of a food web realistic?
8. What are some limitations on our food web?

Transition

- Now that we have made our first model, what claim below can you make about food webs? From our model, which one of the claims do you support? Why?
- Students must pick one claim and come up with at least two supporting pieces of evidence from our model.
- Students will choose a claim and write supporting details on their student handout.

Claims

1. Food webs are very simple.
2. Removing a carnivore would disrupt the entire food web.
3. Food webs only need one green plant.

Give students time to complete their claim sheets. Discuss at least one student's work from each claim.

After the class has discussed their claims, allow them to obtain information from videos and a short article about food webs.

- Now that we have made a model, let's look at a few videos to determine other ways that food chains and food webs are interconnected. We will also read an article that explains key terms in a food web.
  - Video options
    - https://www.youtube.com/watch?v=FFloV2J-eKI
    - http://studyjams.scholastic.com/studyjams/jams/science/ecosystems/food-webs.htm
    - https://aptv.pbslearningmedia.org/resource/thnkgard.sci.ess.chain/think-garden-whats-a-food-chain/#.WsGyi4jwbIU
    - https://www.youtube.com/watch?v=Cd1M9xD482s
- After all students have watched the video and read the article, allow students to revisit their claims.
- Now, based on new evidence students received, how can they still support their claims?

Re-Examining Claim

1. How did the article/video help support your claim?
2. Give at least two supporting pieces of evidence directly from the video or article
3. Is there any information that went against your initial claim?

Students should answer the questions on the student handout. After the students have examined their claims, allow the students to complete the formative assessment concerning a desert ecosystem. Students will complete their own food web based on a desert ecosystem.

Student Assessment

- Pass out a piece of blank white paper, copies of the organisms in the food web, and a student handout to every student.
- Read the following directions to the students: You will be making a food web about the desert ecosystem. Your food web must be clearly labeled, include at least seven different organisms, and have a small paragraph at the bottom explaining the energy flow. Let’s look over the rubric together. Read the student rubric and answer any questions that students might have concerning their food web.
- The students will first cut out all the animals. If students are more comfortable drawing, they are free to draw the desert ecosystem animals.
- On the blank paper, they will glue together and create their own food web.

- Their food web should include the following: a source of energy, producers, consumers, and decomposers. Each organism should be labeled and arrows drawn connecting the images.
- When students are done, they will write a paragraph describing the sun's energy and how it flows through their food web.

Student Assessment Rubric

Components	Comments
Includes at least 7 different organisms	
Arrows show proper energy flow	
Every organism is labeled as producer, consumer, or decomposer	
Includes the sun	
Paragraph explains what the organism eats and what eats it	
Paragraph describes the flow of energy in the food web	
Paragraph describes the role of producer, consumer and decomposer a food web	

Citations and Resources

https://betterlesson.com/lesson/640194/the-food-web
https://www.myips.org/cms/lib8/IN01906626/Centricity/Domain/8123/5th%20grade%20food%20chains.pdf
https://betterlesson.com/lesson/633027/food-webs
http://www.cpalms.org/Public/PreviewResourceLesson/Preview/46523

Student Handout: Food Webs 4.LS2.3

1. **Engage/Review**
   - What is the difference between a food chain and a food web?
   - What are some key things that you would see in a food chain/food web?

2. Food Web Simulation
- Name one thing that you learned from the simulation.
- What was the major source of energy in the simulation?
- What type of organism is normally found on the end of a food web chain?

Claims
1. Food webs are very simple.
2. Removing a carnivore would disrupt the entire food web.
3. Food webs only need one green plant.

Evaluating Evidence from Food Web Model

Claim:	
Evidence:	**Justification (Reasoning) of the Evidence:**

Evaluating Evidence Video/Article

Claim:	
Evidence:	**Justification (Reasoning) of the Evidence:**
Changes from Initial thinking	

5. Formative Assessment - Desert Food Web

- Cut out pictures or draw your own food web using the organisms on the handout. Your food web should include the following: a source of energy, producers, consumers, and decomposers. Please label each organism and draw arrows connecting the images. Under your food web, write a short paragraph explaining how energy is transferred through the web.

Food Web Rubric

Components	Comments
Includes at least 7 different organisms	
Arrows show proper energy flow	
Every organism is labeled as producer, consumer, or decomposer	
Includes the sun	
Paragraph explains what the organism eats and what eats it	
Paragraph describes the flow of energy in the food web	
Paragraph describes the role of producer, consumer, and decomposer in a food web	

Basics of a Food Web

Key points:

- **Producers** - make their own food.
- **Consumers** - get energy by eating other organisms.
- A **food chain** is a linear sequence of organisms through which nutrients and energy pass as one organism eats another
- **Food webs** consist of many interconnected food chains and are more realistic representation of consumption relationships in ecosystems.

Introduction

Organisms of different species can interact in many ways. They can compete, or their relationship can benefit each other. Or, of course, they can do what we so often see in nature programs: one of them can eat the other—chomp! That is, they can form one of the links in a food chain.

In ecology, a *food chain* is a series of organisms that eat one another so that energy and nutrients flow from one to the next. For example, if you had a hamburger for lunch, you might be part of a food chain that looks like this: grass → cow →human. But what if you had lettuce on your hamburger? In that case, you're also part of a food chain that looks like this: lettuce→human.

As this example illustrates, we can't always fully describe what an organism—such as a human—eats with one linear pathway. For situations like the one above, we may want to use a **food web** that consists of many intersecting food chains and represents the different things an organism can eat and be eaten by.

Producers vs. consumers

What basic strategies do organisms use to get food? Some organisms, called *producers*, can make their own food—that is, their own organic compounds—out of simple molecules like carbon dioxide.

Producers are the foundation of every ecosystem on the planet. That may sound dramatic, but it's no exaggeration! Producers form the base of food chains and food webs, and the energy they capture from light or chemicals sustains all the other organisms in the community.

Consumers, also known as other-feeders, can't capture light or chemical energy to make their own food out of carbon dioxide. Humans are consumers. Instead, consumers get their food by eating other organisms or their byproducts and turning that into useful energy. Animals, fungi, and many bacteria are consumers. As we'll see shortly, there are many different kinds of consumers with different ecological roles, from plant-eating insects to meat-eating animals to fungi that feed on debris and wastes.

Food chains

Now, we can take a look at how energy and nutrients move through a ecological community. Let's start by considering just a few who-eats-who relationships by looking at a food chain.

A *food chain* is a linear sequence of organisms through which nutrients and energy pass as one organism eats another. Let's look at the parts of a typical food chain, starting from the bottom—the producers—and moving upward.

Food chains give us a clear-cut picture of who eats whom. However, some problems come up when we try and use them to describe whole ecological communities.

For instance, an organism can sometimes eat multiple types of prey or be eaten by multiple predators, including ones at different trophic levels. This is what happens when you eat a hamburger patty! The cow is a primary consumer, and the lettuce leaf on the patty is a primary producer.

To represent these relationships more accurately, we can use a *food web*, a graph that shows all the trophic—eating-related—interactions between various species in an ecosystem.

- At the base of the food chain lie the **primary producers**. The primary producers are most likely green plants that undergo photosynthesis. The organisms that eat the primary producers are called **primary consumers**. are usually **herbivores**, plant-eaters, though they may be algae eaters or bacteria eaters.
- The organisms that eat the primary consumers are called **secondary consumers**. Secondary consumers are generally meat-eaters—**carnivores**.
- The organisms that eat the secondary consumers are called **tertiary consumers**. These are carnivore-eating carnivores, like eagles or big fish.
- Some food chains have additional levels, such as **quaternary consumers**—carnivores that eat tertiary consumers.

Citation

https://www.khanacademy.org/science/biology/ecology/intro-to-ecosystems/a/food-chains-food-webs

Forest Ecosystem

Trees

Deer

Elk

Squirrels

Insects

Mouse

Raccoon

Coyote

Snake

Rabbit

Great Horned Owl

Black Bear

Grass

Worms

Sun

Humans

Mushrooms

Gray Wolf

Weasel

Oak Tree

Desert Ecosystem

Cacti

Kangaroo Rat

Insects

Lizard

Scorpion

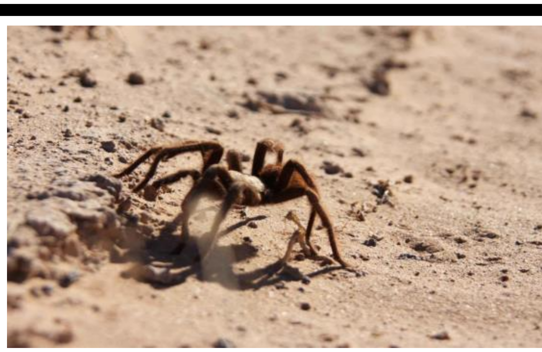
Snake

Desert Cottontail

Desert Fox

Hawk

Meerkats



Tarantula

Desert Tortoise

Shrubs

Sun