TN Department of Education

Teacher Training
Grade 2

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

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Jana Young, Jackson-Madison County Schools

Digital Training Resources

Access Teacher Training Digital Resources here:

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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:

Department of Education

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***

TN Department of Education

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."*

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)

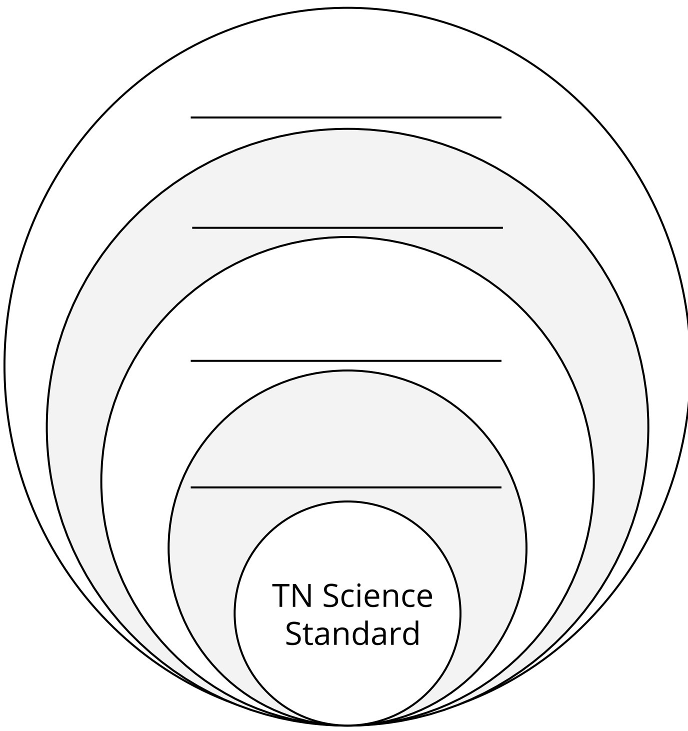
What will my students **do** to learn science content?

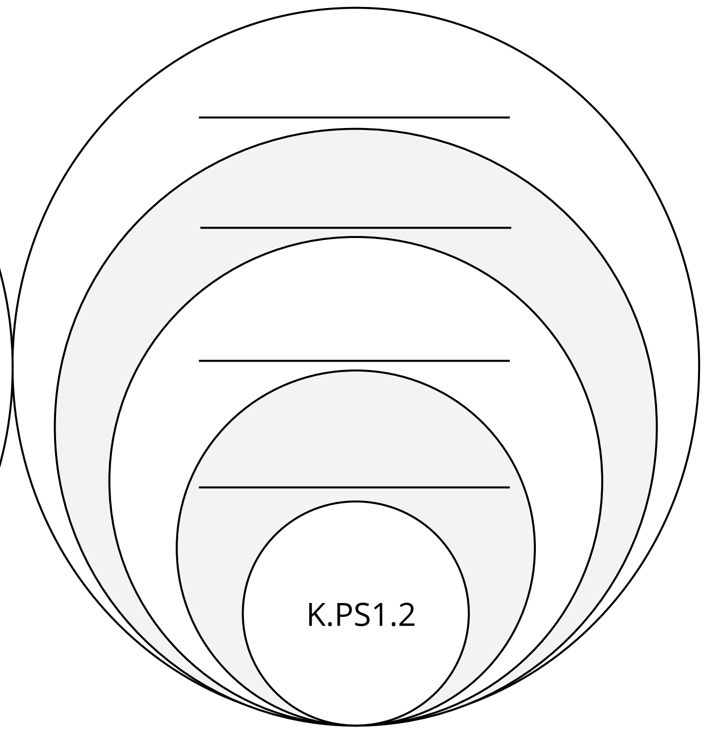
Using Mathematics and Computational Thinking	***Analyzing and Interpreting Data***
Engaging in Argument from Evidence	***Obtaining, Evaluating, and Communicating Information***

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.

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***

Second Grade Standards

2.PS2: Motion and Stability: Forces and Interactions

1) Analyze the push or the pull that occurs when objects collide or are connected.

2) Evaluate the effects of different strengths and directions of a push or a pull on the motion of an object.

3) Recognize the effect of multiple pushes and pulls on an object's movement or non-movement.

2.PS3: Energy

1) Demonstrate how a stronger push or pull makes things go faster and how faster speeds during a collision can cause a bigger change in the shape of the colliding objects.

2) Make observations and conduct experiments to provide evidence that friction produces heat and reduces or increases the motion of an object.

2.PS4: Waves and Their Applications in Technologies for Information Transfer

1) Plan and conduct investigations to demonstrate the cause and effect relationship between vibrating materials (tuning forks, water, bells) and sound.

2) Use tools and materials to design and build a device to understand that light and sound travel in waves and can send signals over a distance.

3) Observe and demonstrate that waves move in regular patterns of motion by disturbing the surface of shallow and deep water.

2.LS1: From Molecules to Organisms: Structures and Processes

1) Use evidence and observations to explain that many animals use their body parts and senses in different ways to see, hear, grasp objects, protect themselves, move from place to place, and seek, find, and take in food, water, and air.

Second Grade Standards

2.LS1: From Molecules to Organisms: Structures and Processes—Continued

2) Obtain and communicate information to classify animals (vertebrates-mammals, birds, amphibians, reptiles, fish, invertebrates-insects) based on their physical characteristics.

3) Use simple graphical representations to show that species have unique and diverse life cycles.

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

1) Develop and use models to compare how animals depend on their surroundings and other living things to meet their needs in the places they live.

2) Predict what happens to animals when the environment changes (temperature, cutting down trees, wildfires, pollution, salinity, drought, land preservation).

2.LS3: Heredity: Inheritance and Variation of Traits

1) Use evidence to explain that living things have physical traits inherited from parents and that variations of these traits exist in groups of similar organisms.

2.ESS1: Earth's Place in the Universe

1) Recognize that some of Earth's natural processes are cyclical, while others have a beginning and an end. Some events happen quickly, while others occur slowly over time.

2.ESS2: Earth's Systems

1) Compare the effectiveness of multiple solutions designed to slow or prevent wind or water from changing the shape of the land.

2) Observe and analyze how blowing wind and flowing water can move Earth materials (soil, rocks) from one place to another, changing the shape of a landform and affecting the habitats of living things.

Second Grade Standards

2.ESS2: Earth's Systems—Continued

3) Compare simple maps of different land areas to observe the shapes and kinds of land (rock, soil, sand) and water (river, stream, lake, pond).

4) Use information obtained from reliable sources to explain that water is found in the ocean, rivers, streams, lakes, and ponds, and may be solid or liquid.

2.ETS1: Engineering Design

1) Define a simple problem that can be solved through the development of a new or improved object or tool by asking questions, making observations, and gather accurate information about a situation people want to change.

2) Develop a simple sketch, drawing, or physical model that communicates solutions to others.

3) Recognize that to solve a problem, one may need to break the problem into parts, address each part, and then bring the parts back together

4) Compare and contrast solutions to a design problem by using evidence to point out strengths and weaknesses of the design.

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

1) Use appropriate tools to make observations, record data, and refine design ideas.

2) Predict and explain how human life and the natural world would be different without current technologies.

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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.

Instruction	
Thinking	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.
Problem Solving	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

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

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

Literacy in the Science Classroom

Speaking	Reading
Writing	Viewing
Showing	Listening

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

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References

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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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The Science Teacher

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?

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.

- *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*

TN Department of Education

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.

<u>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.</u>

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.*

TN Department of Education

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:

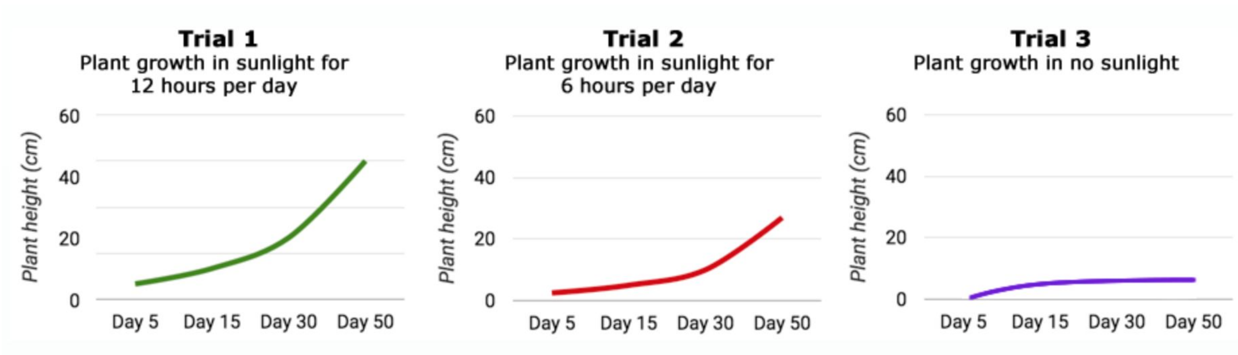
"Students will
compare and refine arguments based on an evaluation of the evidence presented
in order to show
organisms obtain gases and water from the environment and release waste matter back into the environment
highlighting that
matter is transported into, out of, and within systems."

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.

TN Department of Education

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.

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

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?

TN Department of Education

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**.

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: Planning and Carrying Out Investigations

Department of Education

Planning and Carrying Out Investigations

Tennessee Academic Standards for Science

Teacher Guide for Grade 2

Standard
2.PS4.1 Plan and conduct investigations to demonstrate the cause and effect relationship between vibrating materials (e.g., tuning forks, water, bells) and sound.

Tennessee Academic Standards for Science: Page 27

Three-dimensional Learning Performance for Lesson
Students will plan and conduct controlled investigations[*] to show that sound waves transfer energy from one place to another[**] highlighting the cause and effect relationship between vibrating materials and the sound they make.[***]

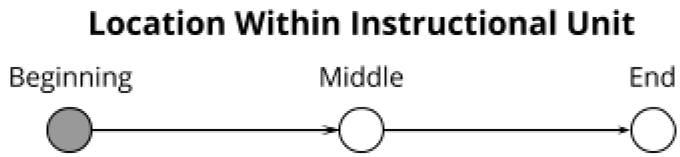
Science and Engineering Practice for Lesson
Planning and Carrying Out Investigations[*]
The goal of this three-dimensional learning performance is for students to visit various stations where they will conduct a series of controlled investigations. Students are provided at each station with instructions and materials for producing or demonstrating sound waves. Students should have sufficient time at each station to experiment with their simple instruments in order to determine what sound waves can be produced and investigate what modifications might be responsible for a change in sound produced by the instrument (e.g., higher or lower pitch and volume).

Disciplinary Core Idea for Lesson
Physical Science 4.A: Waves[**]
“Whether a wave in water, a sound wave, or a light wave, all waves have some features in common...A simple wave has a repeating pattern of specific wavelength, frequency, and amplitude...Sound can make matter vibrate, and vibrating matter can make sound.”

A Framework for K–12 Science Education: Pages 131-132

Crosscutting Concept for Lesson
Cause and Effect[***]
Students identify cause and effect relationships that arise between vibrating materials and the sound waves they produce. As students make modifications to their materials, they will focus on how those modifications make changes to the sound waves they produce.

Prior Knowledge



- Concepts taught prior to this lesson:
    - Though no formal lessons on sound or waves need to have been taught before this lesson, students typically will have experienced a rich variety of sounds by the time they enter second grade and can usually distinguish sounds according to their pitch and volume, though they may not yet be familiar with those specific terms.
    - Students may also have noticed how they seem to not just hear, but feel sounds in their stomach if the sound is low-pitched and loud (e.g., booming thunder, bass instruments in many popular contemporary songs).
    - Students understand that a solid object such as a closed classroom door helps prevent sound from passing through it but doesn't always block sound completely. Students most likely are also aware that covering their ears with their hands or a pillow will reduce, but not always cancel, the amount of volume that they hear.
- This lesson covers portions of standard 2.PS4.1:
    - Sound waves are caused by particles vibrating into each other from the source of the sound, which transfers energy by vibrating and colliding into more distant particles, which then vibrate into yet more distant particles until eventually the particles lose energy and stop vibrating, at which point the sound ceases.
    - Vibrations can be manipulated in two basic ways to impact the sound they produce:
        - 1) We can make the vibrations stronger or weaker with the amount of force we apply to make the sound, which impacts its *volume*.
        - 2) We can modify the vibrations to happen more quickly or slowly, which impacts the sound's *pitch*. For example, this can be accomplished by plucking a rubber band and then stretching the rubber band more tightly before plucking it again.
    - Sound waves can travel through solids as well as the air.*

      **Note: Sound waves traveling through liquid is not covered in this lesson and will need to be explored in a future lesson.*

Materials

- 2.PS4.1 student activity sheet: One per student
- 2.PS4.1 Station Guides: One guide at its respective station
- 'What is Sound?' - YouTube video clip
- Marble Movement Station
  - Two sets of marbles or other small balls - Each set contains at least four marbles/balls
  - Two copies of "How We Hear" article
- Guitar String Station
  - Two empty shoe boxes or empty tissue boxes
  - Six to eight rubber bands in a variety of thicknesses and long enough to stretch over the boxes
- Ticking Desk Station
  - One to two egg timer(s), analog watch(es), or similar device(s) that produce(s) a ticking sound (optional)
  - A pencil or fingers tapping on a desk can also be used as an alternative to egg timers for this station
- Strung Out Station
  - Two pieces of string at least three feet long
  - Four metal spoons (variety of sizes is preferable)
    - Two metal spoons are individually tied toward the middle of each length of string
- Jumping Bean Demonstration
  - One speaker capable of playing music loud enough to vibrate small objects
  - One pack of salt or pepper or a handful of small objects, like rice or beans

Lesson Sequence and Instructional Notes

Class Discussion Opener

The teacher will gather the class to the carpet and write the words "Sounds All Around" on the board. The teacher starts by asking students to think about some common sounds that they might hear and gives students a brief opportunity to share those sounds with a shoulder-partner. After 10-15 seconds, the teacher calls on students to share a sound that either they said or their partner told them. The teacher will record student responses on the board until a variety of sounds are written (e.g., bird chirping, lawn mower engine revving, wet shoes squeaking, horn blowing).

After collecting a number of responses, the teacher will let students know they are about to play a guessing game to identify some basic sounds. Each student receives *Student Activity Sheet 2.PS4.1* and returns to their desk. The teacher has students close/cover their eyes while the teacher demonstrates three basic sounds: 1) a clap of the hands, 2) whistling (if unable to whistle, simply blow air as if simulating wind), and 3) flowing water (by running it from a faucet or pouring water into a cup). These sounds are provided as examples, and teachers may wish to substitute other examples of sounds. If choosing other examples of sound, consider using at least one example that is produced by flowing air or water, so students do not fixate only on sounds caused by solids striking each other such as a banging drum. A variety of sounds can be located here.

After each demonstration, students use their activity sheet to record what they think made each sound. They can also share their guesses briefly with a nearby partner. The teacher reveals the identity of each sound and then asks the class, “So what is sound exactly? What causes sound? Why are sounds different? And how does sound travel to our ears?” Students record what they think might be the cause of sound.

Notes on Possible Student Misconceptions
Students will likely understand that sound is caused by two objects striking each other, such as a clap of the hands or a drumstick hitting a drum. Though it is true that sound requires a medium of vibrating particles in order to travel (e.g., water, air, a stethoscope), it is not always going to be percussive in nature. It may be worthwhile to remind students of other sounds, such as a musician blowing into a flute or the sound of a yawn.

Students Plan and Conduct Controlled Investigations

The teacher informs the class that to understand what sound is and how it moves, students will rotate through four “investigation stations” set up around the room, spending approximately 10 minutes at each station. Each station has a demonstration or an activity on how sound travels and matches with a corresponding section on the student activity sheets. The teacher briefly identifies each station and explains what materials are provided at the station. The teacher also identifies where each *Station Guide* is located, as they contain the directions for each station’s investigation activity. Students will bring their *Student Activity Sheet* with them to each station and are expected to respond to the questions for that station’s section before their time at the station elapses. The teacher should remind students to make sure they match the station they are at with the relevant section on their sheet.

The teacher sets a timer for approximately 10 minutes and begins the timer once all students are at their first station and ready to begin. Once the timer begins, the teacher rotates around the room to reinforce student learning, manage classroom expectations, and provide pointers if any students are struggling with a particular station activity.

Whole-Class Explanation

The teacher calls for students to return items to their stations and meet back as a whole class. Once gathered, the teacher explains that they will be watching a brief video that will help explain how the activities they did tie in directly with sound. The teacher then shows [“What is Sound?”]

Whole Class Demonstration and Formative Assessment

Once the video has finished, the teacher calls the students to a central location where the teacher has set up a music speaker. Close to the speaker is a piece of paper with a few small objects on it, such as dried beans or grains of rice, salt, pepper, or any other small particles. The teacher asks students to turn to the final page of their *Student Activity Sheet* and answer the final prediction questions regarding this last station. Once this is done, students write their names at the top of the last page and turn these in to be collected by the teacher. The teacher will use these responses to formatively assess how well each student understood the lesson. Once the responses have been collected, the teacher turns on the speaker and plays music at a sufficient volume to cause movement in the small objects/particles. Students observe the motion of the small objects/particles as another source of evidence that all sound is caused by, and causes, vibrations.

Teacher Evaluation Notes

Opener/Item 1:
This is an opportunity for students to record their initial thinking regarding sound before they do any investigations. The teacher can use these responses to determine how deep of an understanding students have about sound and if there are particular areas of interest that can be touched on in future lessons to elevate student engagement and relevance.

Marble Movement Station:
The purpose of this station is to investigate how sound waves move. Waves transfer energy from one particle to another without causing the particles to change their location. This understanding should be demonstrated in student sketches that they produce. While some differences in sketches are to be expected, overall student sketches should show that each marble in line bumped into the next marble in line, which transfers its energy as kinetic motion to the following marble. Only the last marble in line should have moved a significant distance away as it had no further marbles to which it could transfer its energy.

Guitar String Station:
This station demonstrates a clear visual relationship between vibrating materials and the sounds produced by those vibrations. As students pluck the rubber bands, they should notice and respond accordingly that when the rubber band is vibrating, it continues to produce a sound. However, when a student touches a rubber band and stops it from vibrating, the sound it was producing ceases as well.

Ticking Desk Station:
Students often understand that solid objects can be effective at stopping sound from going through them. This station is to help deepen student understanding that sound waves do not just stop when they encounter a solid surface, but they travel through that surface a distance relevant to the amount of energy in the wave. The ticking sound should be loud when the students place their ears on the desk. As they move their ear further away from the desk they should notice the ticking sound is not as loud. Students in grade 2 have not yet had instruction on gas as a phase of matter, so for this station, the main takeaway for students is that sound waves are able to travel through solids as well as through air.

Strung Out Station:
This station explores a principle similar to the Guitar String Station but has been included in this lesson because it allows students a better chance to alter the pitch of the sounds they produce. In Part 1 of this station, students should be investigating how the sounds produced by their strings alter depending on how tight the strings are. In Part 2, students investigate how a spoon gently striking a solid surface will sound louder when they are touching their fingers to their ears.

Jumping Bean Activity:
Students investigated in small groups how sound is related to objects vibrating. In this final activity, students deepen their understanding that sound travels through vibrations. If the source of the sound wave releases a lot of energy, the sound wave will transfer that energy in the form of stronger vibrations. If the vibrations in sound waves have sufficient energy, it will cause further objects to vibrate.

Citations and Resources

https://www.exploratorium.edu/snacks/secret-bells

https://www.exploratorium.edu/snacks/head-harp

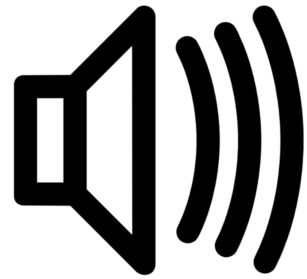
https://citiesandmemory.com/types-of-sound/

https://www.youtube.com/watch?v=3-xKZKxXuu0&feature=youtu.be

"How Sound Works" Article.
https://www.edhelper.com/ReadingComprehension_54_1237.html

Name______________________________

What is sound?



Listen closely to the following sounds. See if you can identify each one!

1. ____

2. ____

3. ____

After hearing these different types of sound, I think sound might be caused by

____

Stop here after you finish recording your responses. If you have some extra time, place your hand on your throat and hum softly as low as you can while keeping your hand touching your throat. Take notice of how your hand feels as you hum—this might be an important clue!

Marble Movement Station

Follow the directions on the *Station Guide* to set up and carry out the investigation.

1. Sketch on the line below what your marble line looked like BEFORE flicking the last marble:

2. Sketch on the line below what your marble line looked like AFTER flicking the last marble:

Speaker image provided by Wikimedia.
https://commons.wikimedia.org/wiki/File:Icon_sound_loudspeaker.svg

Name ______________________________

3. What happens to the motion of a marble when it bumps into another marble?

____

____

Guitar String Station

Follow the directions on the *Station Guide* to set up the investigation and then experiment with it for a couple of minutes.

1. What do you do to the rubber band to make it produce sound?

____

2. What happens to the motion of a rubber band if you touch it immediately after plucking it?

____

3. What happens to the sound produced by the rubber band if you touch it immediately after plucking it?

____

4. What do you predict would happen to the sound of a guitar if a guitar player rested their hand so it was always on the guitar strings?

____

Bonus: Did you find any ways to change the sounds the rubber bands produce? Share any techniques you found in the space below.

____

____

Name ______________________________

Ticking Desk Station

Follow the directions on the *Station Guide* to set up and carry out this investigation.

1. Does the sound of the ticking get softer or louder as you move toward the timer?

   ____

2. Is the sound of the ticking softer or louder when you put your ear up against the desk?

   ____

3. As you move further away from the ticking timer, what happens to the sound?

   ____

Strung Out Station

Follow the directions on the *Station Guide* to set up and carry out this investigation.

1. What happens to the sound of the string when you pull the string tighter and then flick it?

   ____

2. What happens to the sound of the string when you relax your pull on the string a little bit and then flick it? (Hint: You should not relax the string completely, just don't pull it as hard as you did for Question 1.)

   ____

3. As you continue to relax the string more and more and then flick it, how is the sound changing each time?

   ____

4. If you haven't already done so, tie the string around a spoon and follow the instructions on the *Station Guide* for Part 2. When you touch your fingers to your ears and swing the spoon so that it collides with a desk, what happens to the sound?

   ____

Name ______________________________

Jumping Bean Demonstration

1. What do you predict will happen to the small objects once the speaker is turned on?

   ____

   ____

2. What evidence from today's activities and/or video supports your prediction?

   ____

   ____

How We Hear

By Cindy Grigg

1 Have you ever wondered how we hear? Sound travels in waves. If you've ever thrown a rock into a pond or lake, you have seen waves. Waves ripple out from where the rock disturbed the water. Sound travels in waves just like that. Sound waves are vibrations (movements back and forth). We can't see the sound waves. But they move just like ripples move through water.

2 A sound makes particles in the air vibrate. The sound waves travel out from the source of the sound. A bell vibrates when it rings. Then the air particles next to the bell begin to vibrate. The vibration moves through the air in waves. Waves move out in all directions from the source. As sound travels away from the source, it gets weaker. The farther away the sound travels, the softer the sound becomes.

3 You can only hear sound when there is some kind of matter for the sound to travel through. Sound moves through solids, liquids, and gases. Sound travels fastest and most easily through solids. When it travels through liquids, it moves more slowly. It moves slowest of all through gases. In outer space where there is little or no air, sound waves cannot travel. Sounds cannot be heard in outer space. Sound waves must have a medium to travel through. The medium can be a solid like the ground. It can be a liquid like water. Or it can be a gas like air.

4 Imagine trying to catch a small ball. You might cup your hands together. Shaping your hands that way helps you catch the ball. Our ears are shaped like cups to help catch sound waves from the air. Our ears have three main parts.

Grigg, Cindy. 2018, Feb. 20. “How We Hear”. Article retrieved from https://www.edhelper.com/ReadingComprehension_54_1237.html

Marble Movement Station

[1]

1. Read the short article "How We Hear" either alone or with a partner.
2. After reading the article, take four marbles.
3. Put three of the marbles in a line so they are touching (see picture above).
4. Take the fourth marble and line it up with the others, so all four marbles are in a line.
5. Lightly flick the fourth marble toward the line of marbles. Pay special attention to what happens when the marbles bump into each other.
6. Once you have filled out this station's section on your activity sheet, continue to experiment with marbles bumping into each other. What would happen if you put ALL the marbles in this station into one long line and flicked one end of it? If you have time, try it out!

Clean-up Procedure

Find and return all marbles back to their original location before moving on to the next station.

[1] Image hosted at https://pxhere.com/ko/photo/915002

Guitar String Station

1. Take a box and check if there are rubber bands stretched around it. If there are not, take up to three rubber bands, and stretch them around the sides of the box (see picture above).
2. Pluck one of the rubber bands. Notice how the rubber band moves and what sound it makes. Do this for each of the rubber bands.
3. Identify which rubber band makes the highest sound and which makes the lowest sound. Notice anything different that happens to them when you pluck them that might explain why they make different sounds.
4. After plucking each rubber band, immediately take your hand and touch the rubber band. Notice what happens to the sound and to the motion of the rubber band.
5. Compare different box guitars in your small group. Notice if the same size rubber bands always make the same kind of sound or if the sound changes from one instrument to the next.
6. Once you have finished filling out all the questions on your activity sheet for this section, continue to gently experiment with your guitar. See if you can discover a technique to make the lowest string sound higher than the highest string on your guitar. It is possible! (Hint: Plucking the strings harder does not make them sound higher.)

<u>Clean-up Procure</u>

Carefully remove rubber bands from the box guitars and put the rubber bands inside the box. Return the boxes to their original location.

Ticking Desk Station


[2]

1. Set the ticking device on a surface. If no device is available, begin tapping with your fingers or with a pencil on a surface.
2. Listen for the ticks/taps by sitting near the source of sound. Notice the sound of the tick and how loud it is.
3. Now, lay your head down so that one ear is flat against the same surface as the source of sound.
4. As you lay your head down and listen, notice anything about the sound that changes.
5. Notice what happens to the sound of the ticks/taps if you move your head farther or closer to the source of sound. Try this with your head raised off the surface and then try it again with your ear flat on the surface.
6. Notice how far away you are at the spot where you can no longer hear the ticks/taps.
7. Once you have filled out this station's section on your activity sheet, you may take the source of sound around the room and investigate how it sounds on different surfaces. Try ticks/taps on a textbook, on a sweater, on carpet, etc.

Clean-up Procedure
Return the ticking devices, if available, back to their original location.

[2] Image hosted at https://www.pexels.com/photo/black-twin-bell-alarm-desk-clock-on-table-714701/

Strung Out Station: Part 1

 [3]

1. Take a length of string and place the middle of it behind your head.
2. Take the loose ends of the string and gently pull them in front of your head.
3. Place both loose ends of the string in one hand, and move that hand away from your head until the string is nice and tight.
4. With your other hand, gently pluck each one of the strings (see picture above).
5. Notice how the strings sound when you pluck them.
6. Make sure you answer Questions 1-3 before moving on to the next part.

[3] Image hosted at https://www.exploratorium.edu/snacks/head-harp

Strung Out Station: Part 2

[4]

1. Take a length of string that is tied to a metal spoon.
2. Take one end of the string and wrap it two to three times around the pointer finger on your left end.
3. Take the other end of the string and wrap it two to three times around the pointer finger on your right hand.
4. Place both pointer fingers and place them on your ears as if you were trying to block out all noise (see picture above).
5. The metal spoon should hang in front of you, under your head. Keeping your fingers blocking your ears, gently swing the string so that the spoon strikes a surface such as a desk. Notice how loud the sound is.
6. Move your fingers so they are no longer touching your ears, and gently strike the surface of the spoon again on the desk. Notice how the sound changes this time.
7. Compare your results with the other members at your station.
8. Once you have finished this station's section on your activity sheet, investigate what else might change the sound of the spoon striking a surface. Always make sure you GENTLY strike your spoon onto a surface!

[4] Image hosted at https://www.exploratorium.edu/snacks/secret-bells

Tab page front

Label: Analyzing and Interpreting Data

Analyzing and Interpreting Data

Tennessee Academic Standards for Science

Teacher Guide for Grade 2

Standard
2.PS2.1 Analyze the push or the pull that occurs when objects collide or are connected.

Tennessee Academic Standards for Science: Page 27

Three-dimensional Learning Performance for Lesson
Students will analyze and interpret data gathered from observations[*] in order to show that objects in contact with one another act with equal force on each other[**] highlighting that the force that occurs between objects in contact acts on both objects equally.[***]

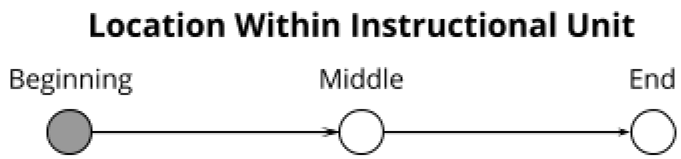
Science and Engineering Practice for Lesson
Analyzing and Interpreting Data[*]
The goal of this three-dimensional learning performance is for students to qualitatively analyze the data gathered from trials to identify patterns that describe the relationship between forces.

Disciplinary Core Idea for Lesson
Physical Science 2- Motion and Stability: Forces and Interactions [**]
"Interactions between any two objects can cause changes in one or both of them. An understanding of the forces between objects is important for describing how their motions change, as well as for predicting stability or instability in systems at any scale."

A Framework for K–12 Science Education: Page 113

Crosscutting Concept for Lesson
Scale, Proportion, and Quantity[***]
In developing their understanding of how forces interact between objects in contact with one another, it is important that students in the younger grades start by making comparisons of the objects using relative scales (e.g., bigger or smaller, closer or further) until they have developed adequate number sense to more quickly interpret quantitative measurements. It is also important for students to consider how scale and proportion may affect forces between objects.

Prior Knowledge



- Concepts taught prior to this lesson:
    - This is the first time that students explicitly encounter forces of motion as part of their science education.*

**Note: Students will have varying degrees of anecdotal evidence that objects which are connected or collide with one another exert a push or pull on each other. For example, a student may have observed a truck pulling a trailer on the road, or railroad train engine car pulling the rest of the railroad cars as it moves down a track. Or a student may have noticed a marker-top leaving a small impression in their hand if they push down hard on it for a few seconds. Students may have had experience playing 'tug-of-war' or a similar activity that requires teams of students pulling on opposite ends of a rope.*

- This lesson covers portions of standard 2.PS2.1
    - Objects that are connected experience a mutual push or pull force depending on if they are traveling in the same direction or in different directions
    - Objects that are not connected but then collide together experience a mutual push force from the collision
    - The force of a push or pull can be qualitatively observed and analyzed to determine that a stronger push or pull may impact objects differently than a weaker push or pull.

Materials
- Two analog body weight scales (digital may be substituted based on ability to read from a number line)
- Five standard marker caps (cylinder shaped)
- Three lengths of rope or durable string, each length approximately two feet long
    - The end of one length tied to a pencil
    - The end of one length tied to a textbook
    - The end of one length tied to a desk
- A rolling chair with wheels
- Marking tape
- One *Station Recording Sheet* per student
- YouTube Video clip: "Eugenia and David Push Each Other"
- (Optional) Safeshare Video clip: "Kenworth Truck Pulling a Flatbed Trailer"*
- (Optional) YouTube Video clip: "100 American Freight Trains!"*

**Note: The optional YouTube clips are provided in case the teacher, during the opening of the lesson, wants to show additional examples of objects being impacted by push and pull forces. The freight train video clip is a lengthy compilation of different trains and should only be viewed for one or two examples before the teacher pauses the clip and moves on with the lesson.*

Lesson Sequence and Instructional Notes

Student Engagement

The teacher opens the lesson by asking students if they can think of any examples where they have seen something push or pull something else. To help students generate some initial ideas, the teacher may choose to show the optional video clip "Kenworth Truck Pulling a Flatbed Trailer" and/or a couple segments from "100 American Freight Trains!".

After students have had a brief time to share any of their experiences, the teacher continues the lesson by sharing a story about how they were roller skating/ice skating with a friend. The teacher noticed when she went to give her friend a helpful push to get him started, she felt an invisible force push them backwards, which was very unexpected! The teacher shows clip "Eugenia and David Push Each Other: Observational Experiment" to demonstrate this force. (It may be helpful to loop the video so students can make repeated observations.)

Students engage in a *turn and talk* activity where they briefly explain to a shoulder-partner 1) what they observed from the video clip and 2) what they think is causing the person initiating the push to move away from the person being pushed. After briefly allowing students to turn and talk, the teacher asks for volunteers to share with the class what they observed and/or why they think the person in the video who did the pushing also moved.

The teacher informs the class that she has set up (or is about to set up) some stations around the room to see what the class can discover about this force. The teacher informs students that they will be recording observations at four different stations to see if they can discover more about what happens when a push/pull force is created between two objects.

Reflections About Potential Student Responses that Might Arise During Instruction
Some students may observe facets of the video not relevant to the lesson (e.g., they are wearing different colored shirts). Consider a follow-up statement and question to redirect their focus: "Interesting observation! But how does that help you discover more about what is happening to the person doing the pushing in the video?"

The big idea here is to get students engaged with the idea of pushing/pulling various different objects to make observations that will be the foundation of their data for this lesson.

Student Activity Stations

The teacher sets up four different activity stations around the classroom. Ideally these stations are set up prior to the lesson, but can also be quickly set up at this time. The class is divided into four equal-sized groups. Each small group will visit one station at a time. The teacher will set a timer, ideally for around 10 minutes, so small groups have the same time at each station. When the timer runs out, each small group rotates to the next station, the timer is reset, and the process repeats.

Station 1: Marker Top Targets
Materials:
One marker top per student

Students grip a marker top in their hand and press it into the palm of their other hand so that it leaves an impression.* Have students experiment to see if/how they can manipulate how visible the impression is. The goal is for students to see if the impression made is affected by whether the marker top is pressed into their hand or whether their hand is pressing on the marker top. Students should observe, record, and be prepared to discuss any differences in the impressions made as they experiment with pushing on the marker top.

**Note: Students should be instructed to only use the marker tops on their own hands and not apply it to any other students in the group. Take care to instruct students not to push so hard on the marker tops that they hurt their hands.*
Station 2: Rope Pull
Materials:
Three segments of rope or string tied separately around each of the following: a pencil, a textbook, and a desk

Students at this station will experiment with pulling a rope tied to different objects to make observations about how the pull force required to move them will change. If the rope is sturdy enough, students may experiment with pulling the objects along the surface of the ground, as well as pulling the objects up into the air. The goal is for students to recognize that objects with more mass require a stronger force to move and that stronger force then acts on both the object and the student pulling on the object. This can be felt by the student because they need to use more strength from their muscles to pull the heavier object. In the case of the desk, it may be very hard for students to pull with enough force to cause it to move.

Station 3: Sumo Scale
Materials:
Two analog/digital weight scales, such as bathroom scales.

Students take turns holding a weight scale vertically close to their chest while facing another student in the group who is also holding a weight scale in the same manner. The students should be able to see the analog read-out on their own weight scale. Students will experiment using their weight scales to push against each other. Students should try having one student push against the other, then they switch roles, then they both push against each other at the same time. During each trial, everyone is observing and discussing the analog read-outs on the weight scales so that everyone in the group knows roughly what each scale's read-out indicated. The goal is for students to observe how the scales will match each other regardless of who is pushing and who is being pushed. They should also notice how when the students push against each other, the scale readings should display the highest level of force.*

**Note: Students should take care to remain in place when pushing or being pushed for this experiment.*

Station 4: Wall Push-Off
Materials:
Rolling chair with wheels, marking tape

Students take turns sitting in a rolling chair with wheels and positioning the chair to be right up against a wall. The student will declare how much force they will push against the wall using words like "light push, medium push, heavy push." They will then push against the wall with the appropriate level of force, which will cause them to roll away from the wall. Students should use the marking tape to indicate the spot where the rolling chair stopped moving. When recording each other's pushes against the wall, students should make sure they are taking note of whether it was a light, medium, or heavy push and relate that information to the location of the marking tape that resulted from that push.*

**Note: Students may be able to use rulers or measuring tape to gather quantitative data. If these are unavailable or if students are not yet ready for number recordings, then they may use qualitative comparisons (e.g., Sal gave a heavy push against the wall, and we marked his rolling chair farther from the wall than Buck, who gave a light push. Jen gave a medium push, and her rolling chair mark is in between Sal's and Buck's.)*

Formative Assessment

It is important that this time involves genuine formative assessment achieved through deliberate selection of demonstrations and use of questioning strategies. Stations should be similar in complexity to allow students to engage at each station with the same amount of time. Two suggested approaches for students to practice analyzing data while engaging in authentic social learning are presented below. A flowchart for selecting questioning strategies appropriate to teaching science is part of [Stem Teaching Tool #35](). The two strategies described below are taken from that flowchart. One rationale for these strategies is to increase a student's comfort level with engaging in discussion by removing the formal academic language and structure of teacher-student discourse. The teacher's role should be to travel through the class, observing the discussions taking place and what role data plays in these discussions.

Share-Trade
Students observe the results of a trial at their station. They write down their understanding of what they just saw and why they think the trial resulted the way it did. Students share their thoughts with a partner. They then trade their writing with that partner, and both partners take each other's writing and share that understanding with a new partner.

Claim-Pass
After students observe a trial at their station, one student writes down a claim at the top of a piece of paper for something they have discovered about the push/pull force occurring between objects (e.g., "I think I moved when I pushed the wall because the push force has to go somewhere, and the wall is too big to move, so I moved"). The paper is passed to each member in the group, and each member adds a piece of evidence or an observation from the trial (e.g., "I moved only a little bit when I pushed only a little bit against the wall"). Students continue to add to each other's thinking as they continue to perform new trials at their station. All thinking is recorded on this one piece of paper. Students can initial their comments or use different colors so the teacher can quickly identify individual comments.

As a final activity, use the daily lesson formative assessment sheet for this lesson: *Analyzing Pushes and Pulls.*
Teacher Evaluation Notes
Item 1:

- Students should insert two arrows between the student and the wall. One arrow points toward the wall and the other points toward the student. A common error might include drawing just one arrow without including the opposite arrow.

- Students should draw an arrow either above or below the arrow provided in the diagram. The student should show the arrow pointing toward the student, and the size/length of the arrows should be consistent. A misconception might include drawing an arrow of a different size/length or facing any other direction than the student.

- Student responses should indicate that the push force between the student and the wall would increase if the student pushed harder. The way we could show that would be by increasing the size/length of the arrows in the diagram. A misconception might include stating that the push force would stay equal because the wall does not move in either case.

Item 2:

- Student sketches can be rudimentary for this item. The sketches should include some representation of a person standing on top of a weight scale. The student indicates the push forces occurring between the person and the scale by drawing one arrow facing up, and another arrow of a similar size facing down. A misconception might include a student drawing arrows facing left and right because they think push and pull forces only happen with lateral movements.

Citations and Resources

"Eugenia and David Push Each Other: Observational Experient"
https://www.youtube.com/watch?v=UZghpgJqUE4

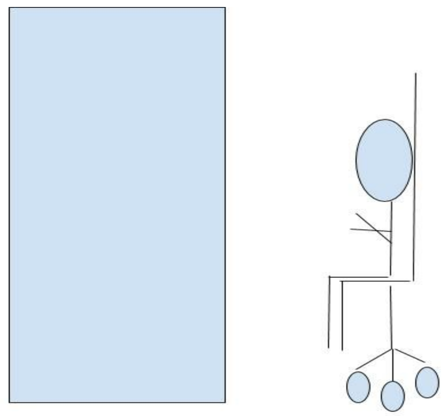
Video excerpt from "100 American Freight Trains!"
https://www.youtube.com/watch?v=N5enjiqtFEo

Video excerpt from "Kenworth Truck Pulling a Flatbed Trailer"
https://safeshare.tv/watch?v=3MoYK_jqlII&from_submit=1

Analyzing pushes and pulls

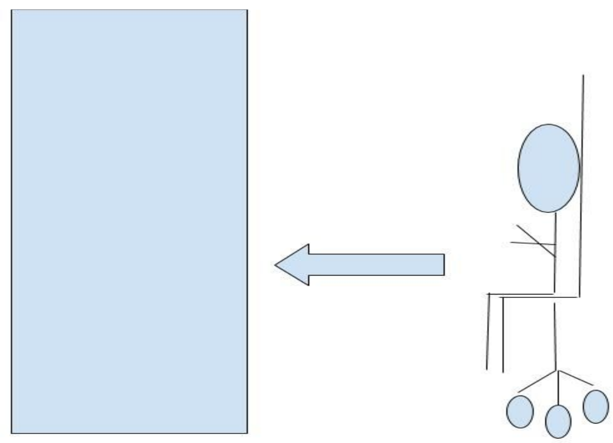
Push and pull forces affect objects that are connected or come into contact with each other. Let's look at some situations and apply what we have learned.

1. Imagine you are sitting in a rolling chair with wheels. You roll the chair over to a large wall. This wall will not move no matter how hard you push against it.



This image represents a student pushing against a large wall while sitting in a rolling chair with wheels.

   a. In the image above, draw arrows to show the push forces that occur between the wall and the student when they push against the wall.



b. In the image above, the force of the student pushing against the wall is displayed as an arrow. Draw an arrow to show how large or small the force of the wall pushing back on the students would be. Keep in mind the size and direction of your arrow.

c. In the image above, what would happen to the force between the student and the wall if the student pushed even harder against the wall? How would we show this change in force using arrows?

____

____

2. In the space below, draw a quick sketch of a student standing on a weight scale. Beside your sketch, draw arrows to show the push forces happening between the student and the scale. Think about which direction each push force is traveling.

Name ___________________________________

Recording sheet for pushes and pulls—mysterious forces

This is your record sheet to keep track of your thinking as you visit each of the four stations around the classroom. Make sure you fill out the section for each station before time runs out. Remember to match each station name to the record sheet so you know you are recording your thoughts in the correct spot!

Initial Thoughts/Turn and Talk: After making observations from the video clip and briefly sharing thoughts with a partner, what do you think is causing EACH person to move?

I think the person BEING PUSHED is moving each time because

____
_

I think the person DOING THE PUSHING is moving each time because

____
_

Station 1: Marker Top Targets

Directions:

1. Take a marker top and lay one hand flat on a flat surface with your palm facing up. Arrange the marker top so it is "standing" on your hand and GENTLY press the marker top into your hand for a few seconds. What do you notice happens to the palm of your hand?

2. Arrange the marker top so it is "standing" on a desk or other flat surface, and this time GENTLY press your HAND, palm down, onto the marker top for a few seconds. You may want to use a different spot on your hand so you can compare the results. What do you notice happens to the palm of your hand?

3. Draw a circle in the table below to show how light or deep the impression in your hand is from the marker top.

	When I push lightly	When I push a little harder
Marker top pushing down → Hand		
Hand pushing down → Marker top		

Station 2: Rope Pull

Directions: Take a rope attached to an object and experiment with the amount of force required to pull it. Try to pull each rope straight up to lift the object into the air. After you have lifted each object with the rope, take the rope and try to pull each object across the floor.

1. What did you notice about the force of pulling each object? Fill in the table below with words to describe the force of the pull, such as “Light,” “Medium,” or “Hard.”

	Pencil	**Textbook**	**Desk**
Pulled up into air			
Pulled across floor			

2. Which object was the hardest to move? How do you know it was the hardest to move?

Station 3: Sumo Scale

Directions: Two members in the group each take a weight scale and hold it firmly at chest level with both hands, so that the scale reading is facing them. One partner is Partner A, and the other is Partner B. Each partner should be able to see the numbers on the scale they are holding. The partners will take turns holding the scales and pushing against each other with them. THE SCALES SHOULD ONLY TOUCH EACH OTHER. Both partners will need to be careful when pushing their scales so the scales don’t slip and go flying. Other group members should assist the partners in observing and recording the numbers on the scale with each push. Partners should switch after three to fours trials, so everyone in the group has a chance to participate and a chance to record.

1. Fill in the table below by writing in the number that was shown on the scale from each trial. You may need to work together as a group to get all the numbers from both scales!

	Partner A _______________	Partner B _________________
Force of 1st Trial		
Force of 2nd Trial		
Force of 3rd Trial		

2. Did the force seem to affect Partner A more? Partner B more? Or both partners about the same?

Station 4: Wall Push-Off

1. When you sat in the chair and pushed against the wall, what kind of push did you use? A light push, medium push, or hard push?

2. Did your push cause you to move? How far did you move?

3. Did your push cause the wall to move? If so, how far did it move?

4. Fill in the table below by adding the words **Not Far, Far,** or **Very Far** in the blanks.

# of tries	I gave a light push	I gave a medium push	I gave a hard push
#1 I traveled….			
#2 I traveled…			
#3 I traveled…			

Tab page front

Label: Engaging in Argument from Evidence

Engaging in Argument from Evidence

Tennessee Academic Standards for Science

Teacher Guide for Grade 2

Standard
2.LS1.1 Use evidence and observations to explain that many animals use their body parts and senses in different ways to see, hear, grasp objects, protect themselves, move from place to place, and seek, find, and take in food, water, and air.

Tennessee Academic Standards for Science: Page 27

Three-dimensional Learning Performance for Lesson
Students will engage in an argument from evidence* in order to show that animals have a variety of external structures to interact with and respond to their environment** highlighting the physical structures contribute to the overall function and survival of the organism.***

Science and Engineering Practice for Lesson
*Engage in an argument from evidence**
The goal of this three-dimensional learning performance is for students to begin to develop the ability to construct a scientific argument based on authentic observations and data, and to be able to defend this argument using evidence. Using evidence from observation, text, or data will enable students to construct an explanation for a scientific phenomenon. The ability to justify or disprove a claim is also a key skill in science, as well as the practice of determining valid evidence or supporting information for an argument. By analyzing the external structures of various animals, students will be able to gather evidence from observation and text to construct a claim about the function of these parts and the vitality of their function to the survival of the organism.

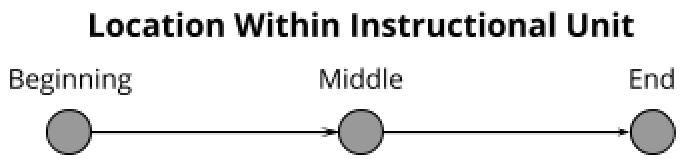
Disciplinary Core Idea for Lesson
*Life Science 1 – From Molecules to Organisms***
"All organisms have external parts. Different animals use their body parts in different ways to see, hear, grasp objects, protect themselves, move from place to place, and seek, find, and take in food, water and air."

A Framework for K–12 Science Education: Page 144

Crosscutting Concept for Lesson
*Systems and System Models****
Students will be able to make connections between the similarities and differences of various external structures and senses amongst the animal kingdom. Students will also describe organisms in terms of their parts and the role those parts play in the functioning

of the overall organism. In summary, students will see an organism as a system, with each external feature and sense acting as a functioning part of that system.

Prior Knowledge



- This lesson covers all of standard 2.LS1.1

Materials

- *What Do You Do With A Tail Like This?* by Steven Jenkins, ISBN: 0-618-25628-8
    - Youtube Read-aloud
- Suggested: Books checked out of the school library about different kinds of animals. Below is a list of suggested books that contain a large amount of information for many animals. Author Stephen Jenkins has several books that are grade appropriate and relevant to this lesson.
    - *Animal Senses: How Animals See, Hear, Taste, Smell and Feel (Animal Behavior)*, Pamela Hickman and Pat Stephens, ISBN: 978-1550744255
    - *National Geographic Animal Encyclopedia* by Lucy Spelman, ISBN: 978-1426310225
    - *The Animal Book: A Collection of the Fasted, Fiercest, Toughest, Cleverest, Shyest – and Most Surprising – Animals on Earth*, by Stephen Jenkins, ISBN 978-054755799X
- *Animal Parts Game*
- “Amazing Animal Armor” text
- “The Big-Eared, Bushy-Tailed Fennec Fox” reading text

Lesson Sequence and Instructional Notes

Teacher Read-Aloud of *What Do You Do With a Tail Like This?*

Begin the lesson by activating prior knowledge. Have students break off into small groups (three to five, depending on classroom size), and assign each group a question listed below. Students can discuss the questions together and come up with a response to share out with the class. Have the questions written on the board so all students can follow along. At this time, the teacher can facilitate and ensure that all students have received this information, or the teacher can fill in any gaps individual students are experiencing in prior knowledge. Since students have primarily focused on plants and humans in prior grades, have students relate back to that information so they may apply their knowledge in a new way. Have the questions written on the board or chart paper so that you may record the student responses for discussion.

Questions

- What are the five senses?
- What body parts do we have that enable us to use our senses?
- How do we grasp objects?
- What structure do plants use to absorb water?
- What structure do plants use to absorb sunlight?

Correct responses

- Five senses = touch, taste, smell, sight, hearing
- Hands, mouth, nose, eyes, ears, etc.
- Humans and primates are unique in that we have an opposable thumb that enables us to grasp and manipulate objects easily.
- Most plants use their roots to absorb water from the soil.
- Most plants use their leaves to capture sunlight and turn it into food.

Discuss the student responses with the class. Using the information that was just gathered (evidence), ask students to make a claim about how an animal uses a body part or sense to survive. You can have students identify an animal that they are familiar with and write a claim about the animal's external parts and how they use them, or you can choose an animal that your group of students will be familiar with. If available, you can provide a picture of the animal to assist students who may not be sure what the animal looks like or to help certain students formulate an idea.

- Example question posted for claim (if students are choosing the animal): What are your animal's external parts and how do they use them?
  Example questions posted for claim (if teacher is selecting the animal): How does a tiger use its eyes? What body parts does a tiger use to get its food?

Student responses should be in the form of a definitive claim. An acceptable student response will answer the question by correctly identifying a body part or sense and providing some form of evidence to support their answer. For example, to the question "What body parts does a tiger use to get its food?" a student could respond with the following answers:

- A tiger uses its legs to chase their food.
- A tiger uses its mouth to bite its food after it has hunted an animal.
- A tiger uses its eyes and ears to seek out and find its food by seeing and listening for other animals.

Have students pair-share their responses and then share with the class. Correct any student misunderstandings or improper use of evidence or claims, while asking probing questions to help students expand their thinking. Examples of appropriate probing questions can include:

- Can you elaborate on…?
- Can you clarify the part about…?
- What do you mean by….?
- Say more about…?
- Can you be more specific about…?

To introduce students to the content of this standard, begin by reading Stephen Jenkins' book, *What Do You Do With a Tail Like This?* If the book is not available, there is a link in the materials section of this document to a YouTube read-aloud video. You can either have the sound playing on the video, or you can mute the video and read it from the screen yourself. For the first reading, just have students actively listen and follow along. After the book has been read once, instruct students that you will read the story again and ask that they complete the first portion of the student activity packet as you read along. Based on classroom population, the book may have to be read again for non-native speakers or differentiation purposes.

Options for students completing this portion:

- Have each student individually choose one animal, and they are required to fill in the portion for that specific animal. Then, everyone shares with the class so all students can fill in the table.
- Assign each student a body part to complete for all the animals in that category. The categories for body parts are from the book. You can refer to the table listed below for body part options.
- Keep your groups from the prior activity (or you can switch them), assign a body part to each group, and allow students to fill in the function for each animal with that body part.

Accepted Student Answers

Animal	**Body Part**	**Function**
Platypus	Nose	Dig in the mud
Hyena	Nose	Find their next meal
Elephant	Nose	Give themself a bath
Jackrabbit	Ears	Keep cool
Bat	Ears	"See"
Cricket	Ears	Hear with ears on their knees
Giraffe	Tail	Brush away flies
Scorpion	Tail	Sting
Monkey	Tail	Hang in a tree
Eagle	Eyes	Spot prey
Chameleon	Eyes	Look two ways
Four-Eyed Fish	Eyes	See above and below water

Chimpanzee	Feet	Feed themself
Gecko	Feet	Walk on the ceiling
Mountain Goat	Feet	Leap from ledge to ledge
Pelican	Mouth	Scoop up fish like a net
Anteater	Mouth	Capture termites
Archer Fish	Mouth	Shoot a stream of water to catch insects

Student Animal Comparison Research

It is important that students begin to develop the ability to find evidence for the use of body parts on their own and begin forming this evidence into a claim. Allow students to choose two animals from the list above that was presented in Stephen Jenkins' book. You can have students work in pairs, or you can place them into groups. If they are in groups, you may want to assign more animals to ensure each student is getting the opportunity to research a body part.

Their goal is to find other ways that these same animals use their external parts. For example, the archer fish uses its mouth to shoot streams of water, but how does it use its eyes? Or its fins? Students will use the provided resources (e.g., books in materials list, pictures, access to technology) to find this information. Students should focus on finding evidence of different structures and their functions for how an animal gathers food and water, protects itself, sees, hears, moves, and interacts with its environment. The claims that students make will focus on how each of these individual parts make the entire organism successful at surviving in its environment. If students need additional guidance and help, you can write some guiding questions on the board. Some suggested questions are listed below.

You can differentiate this activity by having students fill in the other body parts that were highlighted in the book for their animals. For example, if they pick the gecko, the book highlighted its feet, so have students focus on the use of its eyes, mouth, tail, ears, and nose.

Guiding Questions

- How does your animal eat? What evidence supports your thinking?
- How does your animal move? What evidence supports your thinking?
- How does your animal hear?
- How does your animal fend off predators?
- Does your animal do anything unique to survive in its environment?

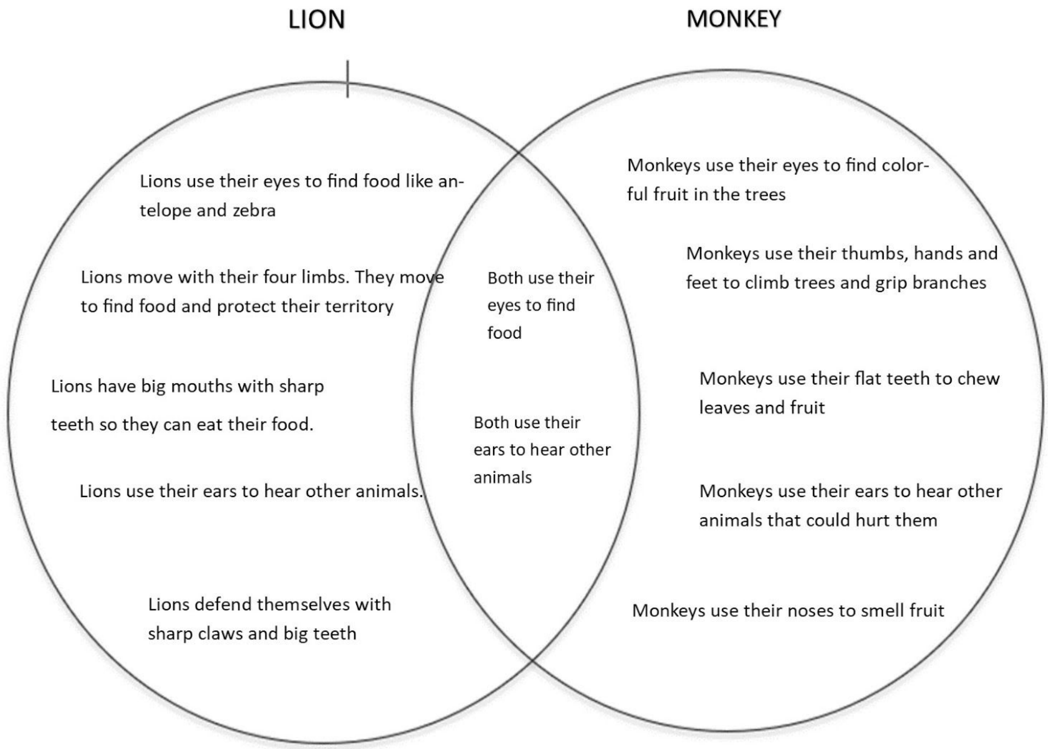
Students can use these questions to help determine the physical characteristics they will find when researching. The evidence they should be examining can be based on observation of the animal pictures in the book or from the textual portion that is explained with each animal in the research sources.

The teacher will model this process of researching and formulating a claim first, and then allow students to choose two animals to research and complete the second portion on the student formative assessment page. Students will use a Venn diagram to record their evidence. This will also allow them to compare and contrast the two animals that they have chosen. Students can work in groups of two to three individuals to complete this portion of the lesson.

Depending on your available resources, you may have to alter this list. Students may also find animals that have really unique ways that they use their senses and body parts. It is suggested to allow students to change this list if they find an animal they really want to learn about in your available resources.

Teacher Model
Draw a Venn diagram, like the one pictured below, on the board. Explain to the group that you will be modeling how to fill this chart out with evidence that you have found about two different animals.

Animal 1: Lion
Animal 2: Monkey



To help students write the claim, you can use the following format as a model:
A(n) ______________________ (animal name) __________________________ [action from standard (see, hear, protect, etc.)] by using their ______________________(structure) to _________________________(function), their ______________________ (structure) to __________________ (function), and their ____________________ (structure) to ___________________________ (function).

Animal #1 Claim
A lion gets its food by using its eyes to see antelope, its legs and claws to chase its food, and its mouth to bite and eat its food.

Animal #2 Claim
A monkey uses its eyes to find fruit in the trees, its hands and feet to climb trees, and its flat teeth to chew leaves and fruit.

Animal Body Parts Game

Up to this point, students have learned how to identify external parts of animals (e.g., nose, ears, eyes) and determine what those parts are used for. This was practiced during the book reading when the information was presented to them, and students were able to practice identifying the part and purpose for different animals through research. Students were only exposed to those that were included in the book, but now they will get to play a game that will allow them to apply these skills to new animals. The game will allow students to get more practice with finding evidence and engaging in an argument. There are cards within the game that can be applied to more than one animal, but there is only one right answer. Students will have to converse about which animal deserves which part and function, use evidence, and argue their position. When students apply the cards to the board, they are using the same format as what they used to write their claims in the research portion. The teacher should be circling the classroom and facilitating positive conversations between students and encouraging students to defend their positions using evidence.

Use the *Animal Body Parts Game* PDF for this activity. It is recommended to print the function cards on one color of paper, and the structure (body parts) cards on a different colored paper. Split the students up into groups of two to four students and have them play one round of the game. Once each group has completed the game, facilitate a classroom discussion and reflection about what they have learned. In order to organize the classroom discussion, have students complete the portion of the student handout in their groups to organize their thoughts. The questions on the sheet are listed below.

1. What did you learn from this game?
2. What external structures are commonly used for finding or getting food?
3. What was one animal that your group disagreed on matching with a body part and function? What evidence did you use to come up with your final answer?

Game Board Answers

Animal	**Body Part**	**Function**
Dolphin	Flippers	Swim
Brown Bear	Claws	Get its food
Owl	Wings	Fly
Monkey	Arms	Swing in the trees
Serval	Ears	Hear its food

Armadillo	Armor	Protect itself
Pangolin	Tail	Hang from trees
Komodo Dragon	Tongue	Smell its food
Red Fox	Eyes	Find its food

Possible Areas for Student Disagreements

This game is meant to enable students to learn to engage in peaceful arguments using evidence to back up their positions. Here are some potential missteps groups may take when organizing their animal cards, structures, and functions:

- Ears and eyes are going to be misused the most. The clue for ears is how big the serval's ears are compared to the other animal options.
- Students may want to use the armor for the pangolin instead of the tail, and that is built into the game.
- Some students may want to put the claws with the serval, but again, the clue is in the picture.

Formative Assessments

Crosscutting concept – How do the parts of the organism described in the scenario work together? (STEM teaching tool #41)

Now that students are familiar with making observations of an animal and drawing evidence about their body parts, they will now have to use these skills in novel ways. The next two assessment portions are scaffolded. In the first scenario, students will read an article and defend a claim using evidence from the text. They will not write the claim themselves; they will only be finding evidence to support the claim already given. From there, students will progress to the second scenario in which they will have to produce a counter argument using textual evidence about fennec foxes.

Scenario 1

Task:

Present students with a claim about a phenomenon then ask students to identify the evidence that supports the claim (STEM teaching tool #30).

Students will read the article "Amazing Animal Armor" and look for evidence in the text to support the following statement: Animals have different methods of protecting themselves with special external body parts.

Students will be required to find and cite evidence from the text and then give an explanation as to why this supports the claim. They should find at least three sources of evidence and then be able to write a statement at the end that supports the claim.

Note to teachers: There is an anatomical and functional difference between spines and quills, even though they may be used interchangeably in some resources. Spines are permanently attached to the body and cannot be released or broken. They are modified hairs that have become hard. Quills, on the other hand, are hollow structures and can be released by the organism. For more information, see the resource listed below from Animal Diversity Web (in the Resource and Citation section of this guide).

Teacher Evaluation Notes

Scenario 1: Support a Claim with Evidence
Students have several animals to choose from with different examples of external parts being used as protection.

- *Full Understanding:* A full understanding would include three different examples of animals and their method of protection through a body part. Below are examples of the final statement students are asked to write after identifying their evidence.
    - Example of statement: Animals use many body parts for protection. The pangolin uses hard scales on the outside of its body, but the armadillo uses a leathery armor. The porcupine uses sharp spines called quills to keep danger away.
- *Partial Understanding:* A partial understanding would only identify two body parts for protection and have two to three examples of supporting evidence.
    - Example: The sea urchin and porcupine both use spines on the outside of their bodies for protection.
- *Limited Understanding:* A limited understanding may only identify one type of protection but have incorrectly identified evidence or lack of evidence to support the statement.
    - Example: The porcupine has spines that are sharp.

Teacher Evaluation Notes

Scenario 2: Produce a Counterargument from Textual Evidence
In this scenario, students will be presented with an incorrect claim and will have to use a supporting text to create a counterargument. This is an essential skill in science and students should use their ability to find evidence in a text and make their own claim that counters the one they have been given.

In this scenario, students will be reading a text about fennec foxes. They were given an incorrect claim about the function of the fennec's large ears, and will have to use the text to find evidence to make a new, correct claim.

- *Full Understanding:* Students with a full understanding of structure and function of animal body parts, as well as the ability to find evidence and write a claim should have an answer similar to the one below.
    - The fennec fox has large ears to help get rid of heat in the hot, dry desert that they live in. Although their ears can help them hear better, the main reason for the size of their ears is for heat loss. Smaller ears are better for colder climates, like the arctic fox, who can still hear well to find prey.
- *Partial Understanding:* Students with a partial understanding will be able to determine the primary reason for the fennec's ears, but may not be able to provide sufficient explanations as to why the other argument is incorrect.
- *Limited Understanding:* Students who are struggling to understand the content behind structure and function of body parts may not find the appropriate function of the ears. They may also struggle with formulating a counterargument.

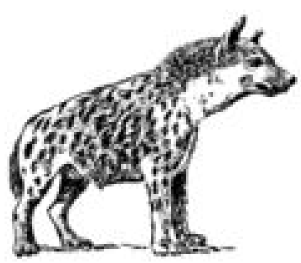
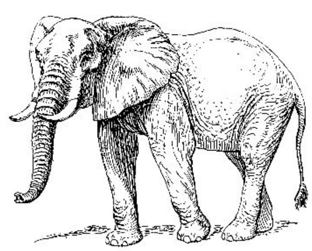
Citations and Resources

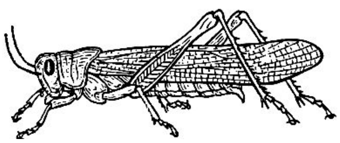
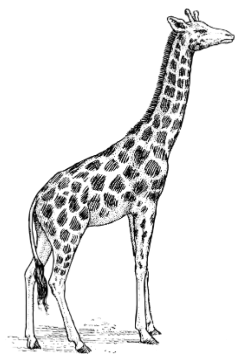
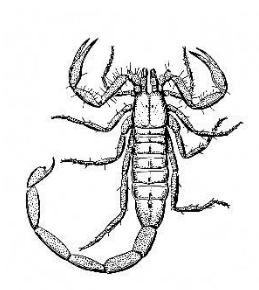
"The Big-Eared, Bushy Tailed Fennec Fox" by Guy Belleranti. Reid Park Zoo, Tucson, Arizona.

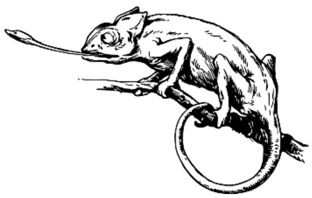
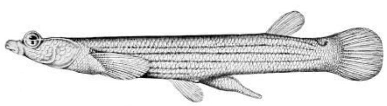
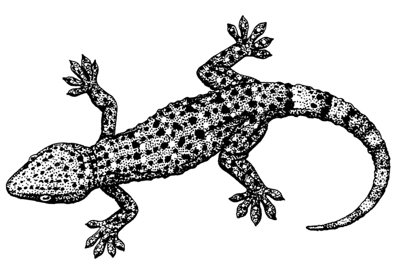
"Spines and Quills" from Animal Diversity Web. Accessed March 1, 2018. http://animaldiversity.org/collections/spinesquills/

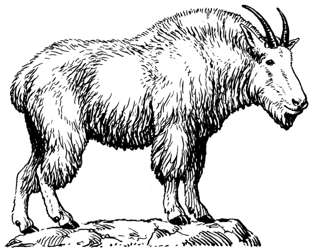
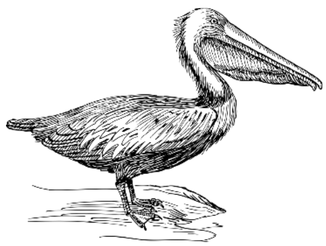
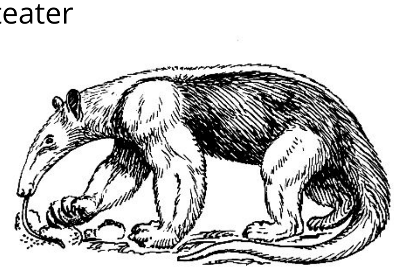
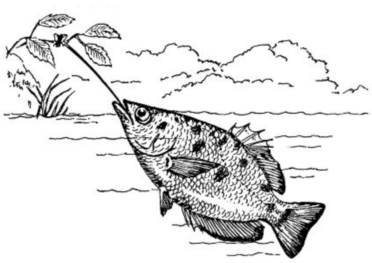
What do you do?

1. Listen closely as the book, *What Do You Do With A Tail Like This?* is read out loud. On the second reading, fill out the following body part and the correct function for each animal.

Animal	Body Part	Function
Platypus  https://upload.wikimedia.org/wikipedia/en/c/c2/Platypus_sketch_by_Hmich176.gif		
Hyena  Pearson Scott Forseman		
Elephant  Pearson Scott Forseman		
Jackrabbit 		

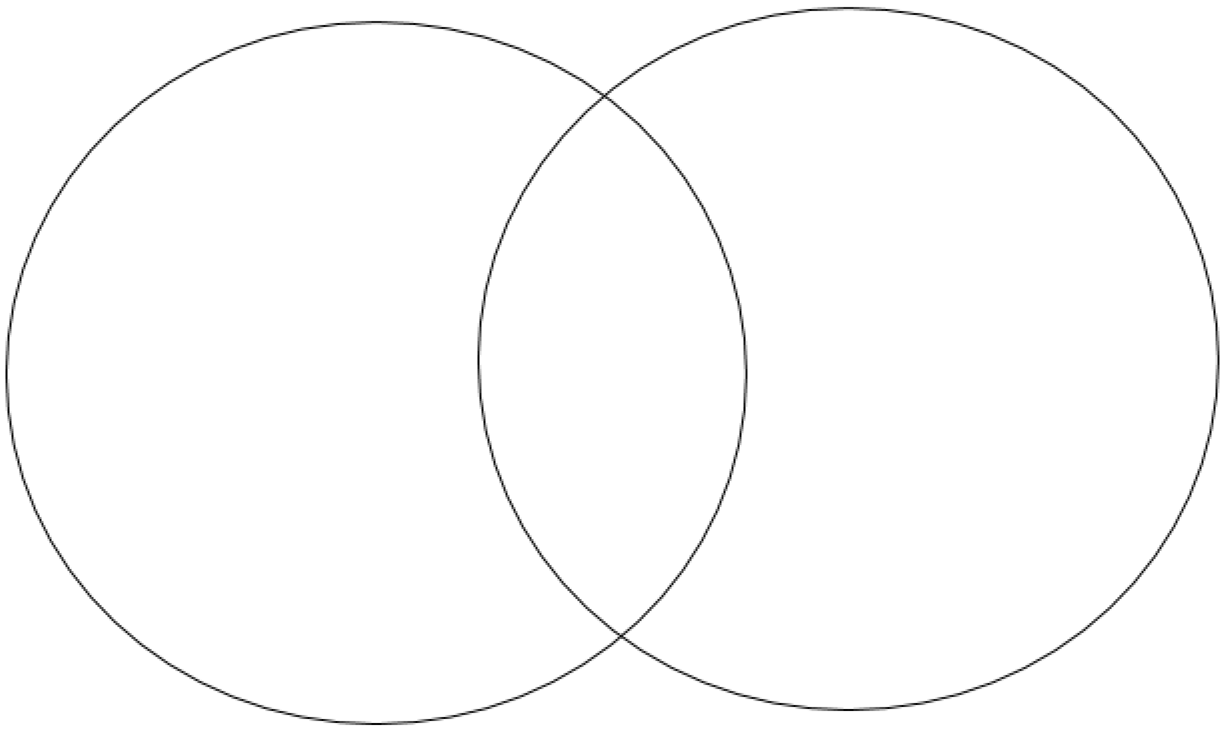
http://2.bp.blogspot.com/-wSnp2oyZ3Lo/UU3DhrpbP9I/AAAAAAAAM7I/bOZzgEYNM1k/s1600/rabbitsketch.jpg		
Bat  https://media.gettyimages.com/illustrations/pen-and-ink-illustration-of-a-longeared-bat-illustration-id128629315		
Cricket  Pearson Scott Foresman		
Giraffe  https://cdn.pixabay.com/photo/2012/05/04/11/13/giraffe-47248_960_720.png		
Scorpion  http://www.publicdomainpictures.net/pictures/170000/velka/scorpion-clipart-illustration.jpg		
Monkey  https://cdn.pixabay.com/photo/2012/04/24/14/05/monkey-40188_640.png		

Eagle  https://cdn.pixabay.com/photo/2016/07/21/16/39/adler-1532967_960_720.png		
Chameleon  https://cdn.pixabay.com/photo/2017/01/31/21/19/animal-2027341_960_720.png		
Four-Eyed Fish  https://upload.wikimedia.org/wikipedia/commons/8/8c/Anableps_anableps2.jpg		
Chimpanzee  https://cdn.pixabay.com/photo/2012/05/07/05/22/chimpanzee-48026_960_720.png		
Gecko  Pearson Scott Foresman		

Mountain Goat  Pearson Scott Foresman		
Pelican  https://cdn.pixabay.com/photo/2017/01/31/22/10/bird-2027638_960_720.png		
Anteater  Perason Scott Foresman		
Archer Fish  Perason Scott Foresman		

2. Choose two animals based on the list that was given to you. Using your resources, find evidence for how each animal uses different body parts and senses to survive in its environment. Fill out the Venn diagram below with your evidence.

Animal #1: ________________ Animal #2: ___________________



In the space below, make a claim about how each animal uses different body parts to gather food, protect itself, move, see, or hear.

Animal #1	Animal #2

3. Animal Game Questions

With your group, answer the three questions below based on the game that you played.

1. What did you learn from this game?

____
____
____
____
____.

2. What external structures are commonly used for finding or getting food?

____
____
____
____
____.

3. What was one animal that your group disagreed on matching a body part and function? What evidence did you use to come up with your final answer?

____
____
____
____
____.

Formative Assessment Sheet

Scenario 1: Support a Claim with Evidence

Read the article “Amazing Animal Armor.” Use the article to find evidence to support the claim given to you below. You should try to find at least three pieces of evidence that support this argument.

Claim: Animals have different methods of protecting themselves with special external body parts.

Citation of Textual Evidence	Explanation of Evidence

Based on your evidence above, write a statement that supports the claim about one way that animals can protect themselves from a predator.

____

____

____

____.

Scenario 2: Produce a Counterargument from Textual Evidence

You are sitting at the lunch table with your friend, Kayla. You are talking about animals, and she shows you a picture of the fennec fox. You notice it has really big ears for such a small animal. You ask Kayla why they have such large ears. She claims it is only to hear things better, since that is what ears are for! You aren't so sure, so you go home and do some reading to see if that really is why this fox has such large ears.

Read the article "The Big-Eared, Bushy-Tailed Fennec Fox," and come up with a counter argument for why this animal has such large ears. Use evidence from the text to support your answer.

Evidence from Article:

Write your counter argument in the bubble below. Remember to use your evidence from the text.

AMAZING ANIMAL ARMOR

About Animal Armor

Animals have all different ways of protecting themselves. Some animals can run fast, some can blend in to its surroundings, but some animals use different kinds of armor for protection. This armor is part of their external body and helps to keep the animal safe from danger. Some examples of armor include hard shells, thick skin, spines, and quills.

External Armor

The first example of an animal having external armor is the pangolin. Although the pangolin looks like an armadillo, it is actually quite different. This scaly mammal lives in parts of Africa and Asia. It's armor is actually made of keratin, which is what human fingernails are made of! The Pangolin uses its armor to stay safe from hungry animals like lions and leopards.

A pangolin! Notice the hard scales on his body.

An Armadillo—can you see how it is different from the pangolin?

Another example of an animal with armor is the armadillo. Armadillos live here in the United States and are another type of mammal. The armor they have covering their bodies is more like leather then a hard shell, but it still helps to keep the animal safe from danger.

Spines and Quills

Other examples of animal armor include spines and quills. One animal that has quills is the porcupine. The porcupine has hundreds of sharp points called quills that stick out from all over its body. When the porcupine feels threatened, it can stick these quills up and help keep danger away. Although some people think these animals can shoot their spines, that is a myth. The spines will come out easily when touched. A picture of a porcupine is shown below.

A porcupine.

A close-up picture of the quills

An animal that uses spines is one that is found in the ocean. The sea urchin is an interesting animal that feeds on the ocean floor. The spines of a sea urchin, like the other examples, help to protect the animal from danger like hungry fish.

Hedgehogs are another animal that has spines. They are mammals. They may look like a porcupine, but they are very different. Hedgehogs will roll into a ball when danger is around and use their spines for protection.

A Sea Urchin

A Hedgehog

ANIMAL BODY PARTS MATCHING GAME

This game is all about matching the right body part and function to the correct animal.

How to play:

1. Stack all of the animal cards face down in the middle of the table.
2. Lay out all of the body part cards on the left side of the animal card stack, face up.
3. Lay out all of the function cards on the right side of the animal card stack, face up.
4. One player will draw an animal card from the middle deck. That individual will then have to choose one body part and one function to match with that animal. Once these are chosen, place them in the correct spots on the board game. When your group agrees, move all the cards in order to the “discard” part of the board.
5. The next player goes, repeating step 4.

Hint—each card is only used once! If you get to the end and your cards don’t make sense, then you need to go back and fix your game board!

Game Board

The (Animal card) uses its (body part) to (function card).

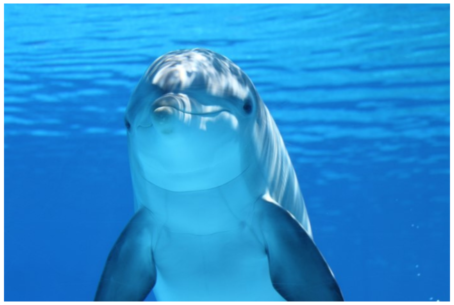
DISCARD USED CARDS HERE

Animal Card

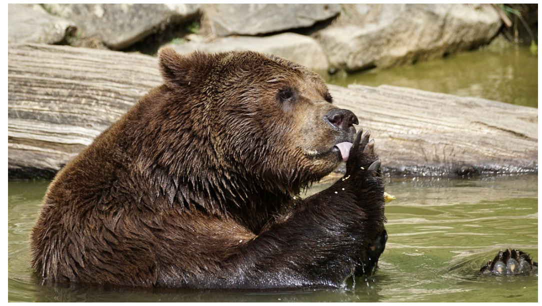
Body Part Card

Function Card

ANIMAL CARDS



Dolphin



Brown Bear

Owl

Monkey

Serval

Armadillo

Pangolin

Komodo Dragon

Red Fox

BODY PART CARDS

Ears	Tail	Eyes
Claws	Tongue	Armor
Flippers	Arms	Wings

FUNCTION CARDS

hear its food	hang from trees	see its food
get its food	smell its food	protect itself
swim	swing in the trees	fly

Tab page front

Label: Obtaining, Evaluating, and Communicating Information

Obtaining, Evaluating, and Communicating Information

Tennessee Academic Standards for Science

Teacher Guide for Grade 2

Standard
2.LS1.2 Obtain and communicate information to classify animals (vertebrates: mammals, birds, reptiles, amphibians, fish; invertebrates: insects) based on their physical characteristics.

Tennessee Academic Standards for Science: Page 27

Three-dimensional Learning Performance for Lesson
Students will obtain and communicate information* in order to show that physical characteristics of vertebrates can classify animals into specific groups** highlighting the specific patterns of relatedness among animal taxa.***

Science and Engineering Practice for Lesson
*Obtain, evaluate, and communicate information**
The goal of this three-dimensional learning performance is for students to begin to develop the skills necessary to draw their own conclusions from a set of data or information and then be able to communicate their findings to others. This is a fundamental skill in both science and engineering practices. In this grade level, emphasis is placed on obtaining the information and evidence from both textual examples as well as a hands-on activity and then communicating (both orally and through writing) the results of the student's investigation. Evaluation of the quality of information will come in later grade bands.

Disciplinary Core Idea for Lesson
*Life Science 1 – From Molecules to Organisms***
"All organisms have external parts. Different animals use their body parts in different ways to see, hear, grasp objects, protect themselves, move from place to place, and seek, find, and take in food, water and air."

A Framework for K–12 Science Education: Page 144

Crosscutting Concept for Lesson
*Patterns****
Students should be able to recognize the similarities and differences between these groups of vertebrates based on the physical characteristics. They will begin to understand that the taxonomic system of classification is organized by patterns exhibited by the animals that are being classified.

Prior Knowledge

- Concepts that should be covered before this lesson:
  - Basic classification
  - Scientific classification
  - Vertebrates vs. Invertebrates
  - Insects
- This lesson covers portions of standard 2.LS1.2:
  - Classes of vertebrates (mammals, birds, reptiles, amphibians, fish)

Materials
- “All About Vertebrates” newsletter
- *Animal Cards* (cut-out sheets included), 15 cards per group
- Large chart paper to hang on walls
- Student Formative Assessment Handout entitled *Classifying Vertebrates*

Lesson Sequence and Instructional Notes

Introduction to Content

Begin the lesson by having students pair-share their thoughts on the five classes of vertebrates. This should be done without any prior knowledge or content introduction. The idea is to get students thinking and relating to their own personal experiences as evidence and being able to share and debate these statements with another student. Students should be filling out the first chart on the student handout to help progress their conversations. Some students may be able to fill out all of the chart; some may not be able to fill in the chart at all. Assure students that it is not expected for them to know all of this information at this point, and encourage them to fill in what they know and leave blank what they do not.

The example column is first in the table to assist students in coming up with animals that they think belong to each class of vertebrate. If they can think of an example animal, then they can use a mental picture of that organism to try to fill out the remaining columns. Even if they have the wrong animal for a certain class, the activity of picturing the animal and drawing information from this mental image is an important skill and should still be encouraged.

Students will likely struggle with the word “amphibian”; the teacher should help students sound out and pronounce the word, but refrain from giving any hints or examples of an animal that represents this group. The purpose of this first activity is to give the teacher a baseline of where students are with their prior knowledge and understanding of this information. Giving students hints will mask any gaps in understanding instead of assisting the student. Give students about 5-10 minutes to fill out what they can in the table. Do not go over the table just yet.

Potential Areas for Misidentification

- Students will most likely struggle differentiating between reptiles and amphibians because they look similar (specifically lizards [reptile] and salamanders [amphibian]).
    - Try to guide students to look at the difference between reptilian skin (scales) and amphibian skin (thin, moist) to help them along.
- Some students may not think snakes are vertebrates at all because they lack the general body plan of all vertebrates (no legs, neck, arms, etc).
- Common misconception: “Fish breath water.” Fish do not breathe “water”; they use their gills to extract oxygen from water. They still breathe “air.”

Acceptable Student Responses

Group	**Animals of this Group?**	**Scales, Feathers, or Fur?**	**Gills or Lungs?**	**Eggs or Live Babies?**	**Warm or Cold Blooded?**
Fish	Trout, bass, tuna, etc.	Scales	Gills	Eggs	Cold Blooded
Amphibians	Salamanders, frogs, toads	None (actually have smooth, moist, thin skin)	Both	Eggs	Cold Blooded
Reptiles	Snakes, lizards, crocodiles, turtles	Scales	Lungs	Both	Cold Blooded
Birds	Hawks, eagles, sparrows, etc.	Feathers	Lungs	Eggs	Warm Blooded
Mammals	Deer, cats, dogs, etc.	Fur	Lungs	Live Babies	Warm Blooded

Obtaining Information

Students will use reading strategies to obtain information from the “All About Vertebrates” text. Below is a recommended strategy for students to become familiar with annotating and highlighting an article in science. Other reading strategies may also be substituted here as long as students are able to pull the necessary information to complete the table in the student guide and progress through the remainder of the lesson.

1. *Guided Reading:* At this time, the teacher will read the article out loud to students. Students should highlight all titles that they see in "blue" highlighter (or underline if highlighters are not available).
2. *Individual Reading and Highlighting for Detailed Information and Evidence:* Once the teacher has read the article once, students can now pair up to read it again with a partner. Because they already highlighted the titles in the first reading, students will now use a yellow highlighter to highlight any details (evidence for physical traits of each group) they find under each blue title. If students have a question about a word or sentence, they can circle it and ask the teacher for help and guidance.
3. *After Reading:* Students can then go back and fill in blanks to the second table. The partners can work together to fill in any additional missing information that they had in the first table as well. This will enable students to practice obtaining information from a text, sharing and communicating it with a partner, and writing the evidence in appropriate locations on the student handout.

Once this activity is completed, students should have two completed tables on their student handout. Below are potential responses from students after completing the reading:

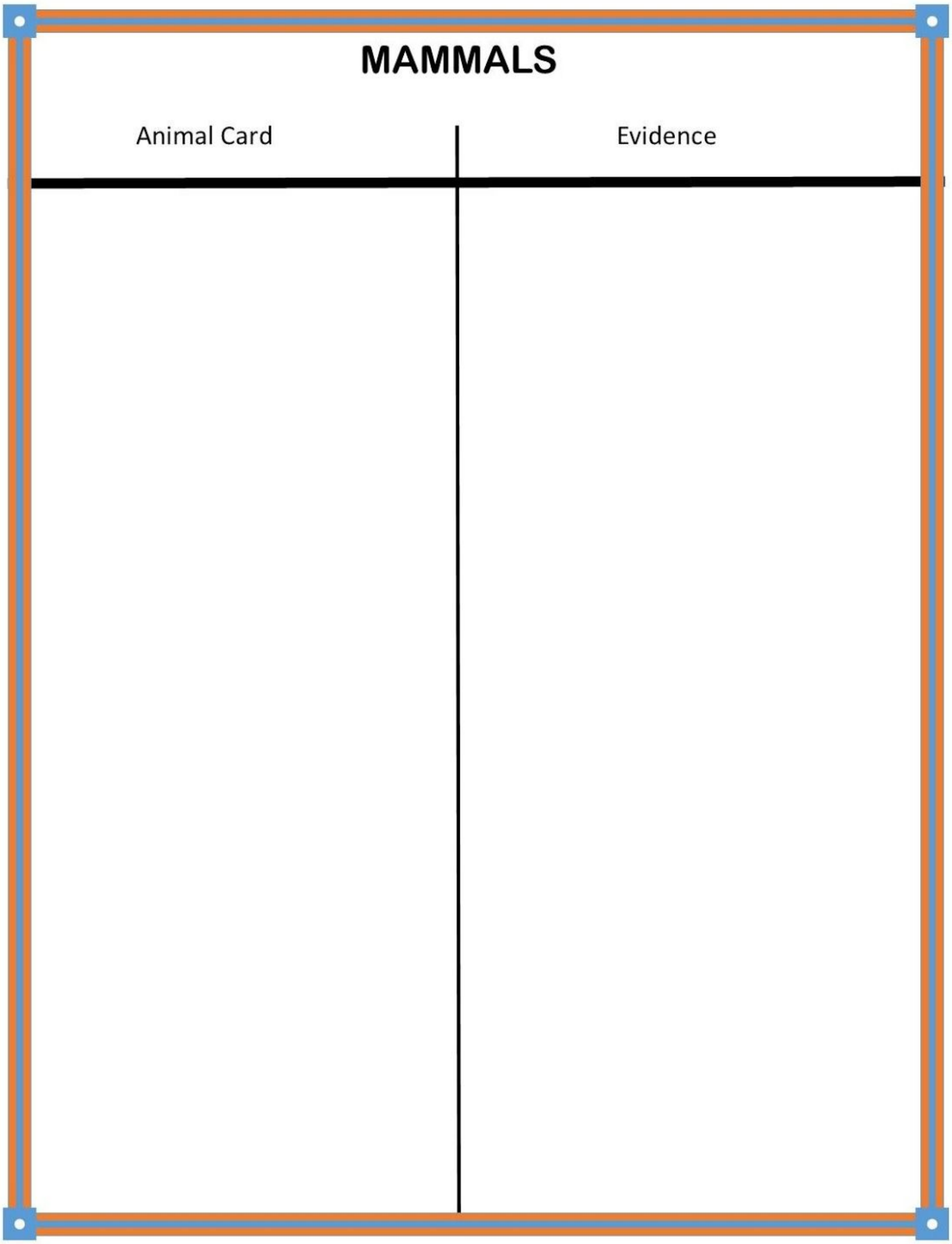
Acceptable Student Responses

Mammals	Birds	Reptiles	Amphibians	Fish
• Bodies are covered in fur or hair • Give birth to live young • Warm-blooded	• Feathers • Wings • Beak • Walk on two legs • Warm-blooded • Lay eggs	• Have scales • Cold-blooded • Some lay eggs • Some give birth to live young	• Covered in thin, moist skin • Lay eggs in water • Most have lungs	• Covered in scales • Have gills • Fins, tail • Live in water • Lay eggs

Activating Student Thinking

Crosscutting Concept: What is one way you could classify or group these animals to create groups of five that are similar to each other?
Students will be immersed in the content of this lesson through a hands-on activity. Have five pieces of chart paper posted around the classroom. Label each piece of paper with one

of the classes of vertebrates (fish, amphibians, reptiles, birds, and mammals). Then, draw a line directly down the middle. Students will be placing the animal cards on the left side of the chart, and the evidence for their placement (the physical characteristics) on the right side (see model picture below).



Crosscutting Concept: Describe the attributes (characteristics) you are using to classify each of the groups of vertebrates.

Activity Overview

- Assign groups and explain directions
- Hand out cards to groups
- Model how this process should be done
- Students complete first part of the activity (classifying the cards on their desks)
- Chart paper portion
- Adding textual evidence

Activity Directions

Split students up into small groups (two or three students), and give each group a set of animal cards. There are 15 total cards, and each group will receive the same animal cards. Have students work together to identify the physical characteristics of each animal on the cards and begin identifying similarities and differences between the animals they have. Students should fill out Part 3 on the formative assessment handout as a group. They should also be physically grouping the pictures on their desk or table into the five different categories. The teacher should be walking around and taking notes of student conversations, discussions of evidence, and placement of their cards. It is important to remind students that they can only use evidence that they see in the picture. At this time, they should not be referring back to the text for information. For example, if an animal is classified as a "bird," then the evidence should be strictly about physical characteristics that they can identify on the card. "Lays eggs" should not be included as evidence at this point, since none of the pictures show a bird laying eggs.

Once all students have completed the activity, they can go up and stick the cards to the groups they want to classify them in (if students need assistance or differentiation, it may be beneficial to place one example on each piece of chart paper so students can begin to associate that group with a specific set of animals). The teacher can decide how to assign this—each group can have copies of the chart paper, or the teacher can assign specific numbers to each group that will be responsible for placing the cards up on the chart paper. (However, each group should get the practice of classifying all 15 animals, even if they are not the group responsible for placing them on the paper.) Once all students have placed their animals, allow the whole class time to rotate to each paper and discuss animals that they think may have been misidentified. Have students begin the conversation (using evidence) as to why they think an animal should be moved and to where it should be moved. This will help students begin to develop the skill to communicate their ideas using evidence. As the teacher, you can purposely place cards in wrong spots to ensure this type of critical thinking will occur.

- Students will most likely confuse the skinks (Animal #11) in this activity. They may identify them as an amphibian, when they are in fact a reptile. These animals and this picture were specifically chosen to elicit this possible response. In the other reptile cards, the scales on the animals are clear and easy to see. The skink picture lacks this clarity, so they need to rely on other cues to properly classify the animal.

- All of these animals were specifically chosen because they are native to Tennessee.

Teacher Model

Since this may be a new skill to most students, it is best for the teacher to model not only how to complete this activity but how to approach obtaining evidence from a picture. Use the model picture of a Largemouth Bass (fish) that is included on the card sheet.

Have students look at this model card with you as you model. Below is a list of statements or questions that will model the type of thinking necessary to complete this activity. Inform students that these are the types of thoughts and questions that they should use when they are analyzing each animal card. The teacher can either answer these questions out loud themselves or have student volunteers answer them as the teacher asks them.

- Does the animal have scales, feathers, or hair/fur?
- Does the animal have fins, wings, or legs?
- Does the animal have obvious ears, nose, and eyes? Or does it have gills?
- Where does it look like the animal lives?

Once you have modeled the thought process for students, allow them to begin the activity. The teacher may demonstrate another animal together as a class from the cards if they feel the class needs additional direction.

Acceptable Student Responses

Animal Number	**Type of Vertebrate?**	**Evidence**
1	Amphibian	No scales, skin looks slimy Salamander
2	Amphibian	No scales, skin looks slimy Frog
3	Bird	Feathers, wings, beak
4	Mammal	Fur
5	Fish	Scales, gills, lives in water
6	Amphibian	No scales, skin looks smooth Newt (salamander)
7	Reptile	Scales present Lizard
8	Bird	Feathers, wings, beak
9	Fish	Scales, gills, lives in water
10	Mammal	Fur

11	Reptile	Scales present Skinks
12	Bird	Feathers, wings, beak
13	Mammal	Fur
14	Reptile	Scales present
15	Amphibian	Skin looks slimy, no scales Frog

Once students have properly placed all animals, invite students up again to now include evidence from the text. Give students different color markers so they can distinguish evidence received from the pictures versus evidence obtained from the textual document. This allows students to practice obtaining evidence from two different sources and combining them into one response. This can be information that is not physically represented on the cards, like a bird lays eggs. In the table below, you will see all of the appropriate responses from both the picture and the text. This table also includes the identification of each animal, in case students question what each animal is.

Teacher Discussion Points

- If students write “scales” as the only answer for the reptiles, ask them what makes the animal a reptile instead of a fish, since fish also have scales.
- Encourage students to look for the patterns in their evidence. Facilitate discussion (referring back to their original table and the second table) to identify the typical physical characteristics that are used to classify each class of vertebrate.
- If some animals are lacking in evidence, encourage student participants to come up and add additional information.

Final Student Responses

Animal Number	**Type of Vertebrate?**	**Animal ID**	**Evidence**
1	Amphibian	Marbled Salamander	No scales, skin looks slimy Text: lays eggs in water, in wet environment, cold-blooded
2	Amphibian	Wood Frog	No scales, skin looks slimy Text: lays eggs in water, in wet environment, cold-blooded
3	Bird	Blue Jay	Feathers, wings, beak Text: lays eggs, warm blooded
4	Mammal	Racoon	Fur

			Text: gives birth to live young, warm-blooded
5	Fish	Brook Trout	Scales, gills, lives in water Text: lays eggs in water, cold-blooded
6	Amphibian	Red Spotted Salamander	No scales, skin looks smooth Text: lays eggs in water, in wet environment, cold-blooded
7	Reptile	Eastern Fence Lizard	Scales Text: lives in dry environments, lays eggs
8	Bird	Field Sparrow	Feathers, wings, beak Text: lays eggs, warm blooded
9	Fish	Catfish	Scales, gills, lives in water Text: lives in dry environments, lays eggs
10	Mammal	Black Bear	Fur Text: gives birth to live young,warm-blooded
11	Reptile	Broad Headed Skink and Common Five-Lined Skink	Scales Text: lives in dry environments, lays eggs
12	Bird	Red Tailed Hawk	Feathers, wings, beak Text: lays eggs, warm-blooded
13	Mammal	White Tailed Deer	Fur Text: gives birth to live young,warm-blooded
14	Reptile	Rat Snake	Scales Text: lives in dry environments, lays eggs
15	Amphibian	Spring Peeper	Skin looks slimy, no scales Text: lays eggs in water, in wet environment, cold-blooded

Additional Teacher Information for Each Group

This is strictly to enhance teacher background knowledge and not intended for sharing with students, unless questions arise.

Group	Likely Student Responses	Additional Teacher Information
Mammals	• Fur/hair • Presence of mammary glands (produce milk) • Presence of teeth*	• *Mammals are the only group that have a heterodont dentition, meaning there are multiple types of teeth used for specific jobs (includes canines, incisors, molars, premolars, and other specialized teeth). • Presence of inner ear bones • Sweat glands • Four-chambered heart (found in birds and crocodiles) • Viviparous (giving birth to live young) • Endothermic (warm-blooded)

Birds	• Feathers (this is the only true defining physical characteristic to birds)
	• Presence of wings [be sure to explain insects and bats (mammals) have wings too]
	• Have a beak (no teeth)
	• Walk on two legs
	• Lay eggs in nests (shared with reptiles)
		• Other characteristics include hollow bones and presence of a sclerotic ring around eye socket (shared with reptiles)
		  o Shared traits: endothermic, four-chambered heart
		  o Feathers (with certain lineages of dinosaurs)

Reptiles	• Scaly skin • Presence of teeth (homodont dentition – all teeth are the same, with exception of snake fangs for venom transference)	• Additional characteristics may include ectothermic, claws on feet and hands, *most* are oviparous (lay eggs) but there are species that can give birth to live young
Amphibian	• Thin, slimy skin • Lay eggs in water • Pedicellate teeth	• Additional characteristics include ectothermic, subcutaneous respiration (some are able to “breathe” through their skin), some salamanders do not have lungs, reliance on water, paedomorphosis (retain juvenile

		characteristics, primarily external gills) ● Some species of salamanders can give birth to live young
Fish	● Scales ● Gills ● Lives in water	● Additional characteristics include external fertilization, ectothermic, most do not have lungs, presence of swim bladders (assists in spatial orientation in the water)

After all of the information is correct on the chart paper and the teacher has discussed it with the class, students should answer the question that is on their student handout. This is a quick check to make sure students understand the process of classifying animals using the physical characteristics.

Big Question
How can you use patterns of physical characteristics to classify animals into specific groups?

Correct response
Animals that have similar characteristics, like fins, gills, and scales, should be grouped together, but animals that have different traits, like legs or fur (different from fins and scales), should be placed in another group.

Use the daily lesson formative assessment sheet—*Classifying Vertebrates*—for the remaining parts of the lesson.

This formative assessment sheet is going to focus on the 3D learning aspect of this lesson. Once students have identified the primary physical characteristics used to distinguish the five classes of vertebrates, they will then have to apply these skills to a real-world scientific scenario by classifying a mystery animal using the patterns of physical characteristics for each group and providing written evidence to communicate their claim. Following this task, students will then be provided with a grade-appropriate text related to this content and construct an explanation to communicate their ideas.

Teacher Evaluation Notes: Scenario 1

Item 1 (Obtain Information):
In their initial evaluation of the picture, students should identify the following features: the animal has two legs, two arms, and a tail, a defined head and mouth, animal has scales covering surface of the body. The animal has brightly colored skin with unique patterns of black and white spots, animal has fans or “raised” parts on back, head, and tail.

- *Partial Response:* Presence of scales, head, tail and legs
- *Limited Response*: Presence of head, tail, and legs

Item 2 (Evaluate Information):
Students should now be able to recognize the patterns of classification for each group of vertebrates. Students who correctly identified that the organism is covered in scales, but lacks any characteristics of a fish (fins, gills, etc.), will be able to correctly identify the animal as a reptile. Some students may also be able to call it a “lizard” in their responses to this question. The evidence they provide should include the scales that are present, but can also include the description of the overall body plan of the animal (legs, arms, etc).

- *Partial Response:* Animal is a reptile, but may lack the connection to any physical characteristics, especially the scales
- *Limited Response:* Students are unable to make a connection between any defining physical characteristics to one specific group. A common mistake may be identifying this animal as an amphibian instead of a reptile.

Item 3 (Communicate the Information):
For this item, students should be able to synthesize their classification of a reptile and their evidence of physical characteristics into one well-constructed response. Students should be able to formulate a response similar to the one provided below (responses may vary based on student writing ability and differentiation needs; however, the information presented should remain consistent between responses).

Example Response:

Dear Costa Rican Government,

I have been able to identify a new species of *reptile* while on my trip. This animal is classified as a reptile because it lives on land and has scales covering the entire body, which are patterns found only in reptiles.

Teacher Evaluation Notes: Scenario 2
Item 1 (Use a text to construct an explanation classifying an organism based on physical characteristics):
Student responses may vary for this item:

- *Full Understanding:* A student with a full understanding of this lesson will identify the animal as a bird based both on the evidence given in the text but also based on their knowledge of defining characteristics of the different groups of vertebrates. In their responses, students should discuss the presence of wings and feathers (as evidenced by the textual description of “red feathers” and when the animal “flew” to a different tree), and supplement information that the animal likely has a beak. To constitute a full understanding, the student should accept the fact that the animal has two legs, but counter Jordan's argument that all birds walk on two legs as well, and note humans are one of the few mammals that have this ability. The student can reiterate the fact that this animal has feathers *instead* of fur or hair, which immediately makes it a bird.

- *Partial Understanding:* A partial understanding will likely include evidence strictly from the text, focusing only on the fact that the animal has feathers and can fly. Incomplete responses will lack the evidence from prior knowledge (likely the presence of a beak) and will lack the rebuttal to Jordan's assertion that walking on two legs classifies an animal as a mammal.
- *Limited Response*: A limited response may include some of the following scenarios:
    - The student is unable to identify why Jordan is incorrect at all.
    - The student is able to make a connection between the feathers and a bird, but can't directly state the evidence to make their claim.
    - The response lacks the rebuttal to Jordan's assertion that it is a mammal.
    - The response lacks any evidence from prior knowledge.
    - The student may only use one source of evidence from the text (either the feathers or flying), but not both, in their response.

Classifying Vertebrates

1. Talk with your partner and try to draw evidence from personal experiences and prior knowledge to fill out the table below.

	Name Animals in this Group.	Scales, Feathers, or Fur?	Gills or Lungs?	Eggs or Live Babies?	Warm or Cold Blooded?
Fish					
Amphibians					
Reptiles					
Birds					
Mammals					

2. Read the text that has been provided. Based on the information given in the reading, adjust your identification of the physical characteristics of each group by listing them in the table below.

Mammals	Birds	Reptiles	Amphibians	Fish

3. Group your animal cards into the five different classes of vertebrates based on the traits you have identified in the first two tables. Work with your group to make sure that each animal is placed in the correct category. In the table below, indicate the identification of each animal and the evidence that you and your group used to classify that animal.

Animal Number	Type of Vertebrate?	Evidence
1		
2		
3		
4		
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12		
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14		
15		

Big Question: How can you use patterns of physical characteristics to classify animals into specific groups?

____

____.

Scenario 1:
You are a scientist studying the natural world in Costa Rica. You have been asked by the Costa Rican government to try to find a species that is new to science. So far, you have only found animals that have already been identified. Two weeks into your trip, you have come across an animal that looks like what is pictured below. You believe it is a new species of vertebrate, and so you now must classify it.

Photograph by: Connor Long

1. Based on the picture, what physical characteristics does this organism have?

2. To which vertebrate group would you assign this animal based on the characteristics you have identified?

3. Now that you have identified the new species, please communicate your findings to the Costa Rican government. Remember to include the evidence you have obtained about the animal to support your classification.

Scenario 2:
Read the following story and answer the question below.

You and your friend Jordan are walking home from school. Jordan points to a nearby tree and states, "Look at that animal in the tree!" You look in that direction and notice an animal with red feathers sitting in the branches. "Oh, that's just a bird," you reply. As you state that it is a bird, the animal opens its wings and flies to a different tree. "That's not a bird!," states Jordan. "That's a mammal! See how it walks on two legs? We walk on two legs and we are mammals, so that must be a mammal!" You respond, "Well that is true, but not everything that walks on two legs is a mammal." Jordan still disagrees with you and asserts that this animal is in fact a mammal.

4. How would you respond to Jordan's identification of this animal being a mammal? What is some evidence that you can use to prove this animal is a bird? In the space below, write a response to Jordan explaining that this animal is a bird.

All About Vertebrates

How to Classify the Five Classes of Vertebrates

INTRODUCTION

Vertebrates are animals that have a backbone and an internal skeleton. There are about 40,000 different species of vertebrates in the world. These animals are broken up into five main groups: Fish, Amphibians, Reptiles, Birds, and Mammals. Animals within each group share certain physical characteristics. You can use these physical traits to help classify other animals into one of the five groups.

MAMMALS

Mammals are one of the more familiar groups of vertebrates. They include animals like dogs, cats, and squirrels. Mammals are classified by having fur or hair that covers their bodies. Not all mam-mals will be furry, though.

Animals like elephants, dolphins, and humans are classified as mammals even though they don't have a thick coat of fur like a bear. Almost all mammals give birth to live young and they are warm-blooded.

BIRDS

Birds are the only group of living vertebrates that are covered in feathers.

Feathers are actually modified scales. Birds also have wings and beaks, as well as walk on two legs, although these characteristics are shared by other groups. Birds are warm-blooded. All birds lay eggs, but not always in a nest.

REPTILES	AMPHIBIANS	FISH

REPTILES

Reptiles are another group of vertebrates. Most people think about snakes and lizards when they think of a reptile.

This group also includes crocodiles, alligators, turtles, and dinosaurs. Rep-tiles have thick scales and usually prefer to live in dry environments.

They are cold-blooded and some species lay eggs, like crocodiles and turtles, but some reptiles can give birth to live young, like some lizards.

Reptiles breathe through their lungs and live in many different types of environments.

AMPHIBIANS

Amphibians are a group of vertebrates that share certain physical characteristics.

All amphibians have thin, moist skin that helps them take in oxygen from their surroundings, but most still have lungs.

Some species even have gills! Amphibians also lay their eggs in water, such as ponds. There are three main animals that are classified as amphibians: frogs and toads, salamanders, and caecilians.

FISH

Fish are classified as vertebrate animals that have scales, gills, fins, and live only in water. Some other physical characteristics of fish include being cold-blooded, have tails, and lay eggs.

Most species of fish do not have lungs. Instead, they use their gills to breathe. Fish do not breathe water, as some may think, but they breathe oxygen like animals on land. The gills are able to pull oxygen from the water and be ab-

SUMMARY

- There are five classes of vertebrates.
- The groups are: mammals, birds, reptiles, amphibians and fish.
- Each group has different physical characteristics.
- Groups are classified by these different physical characteristics.

Animal #1

Animal #2

Animal #3

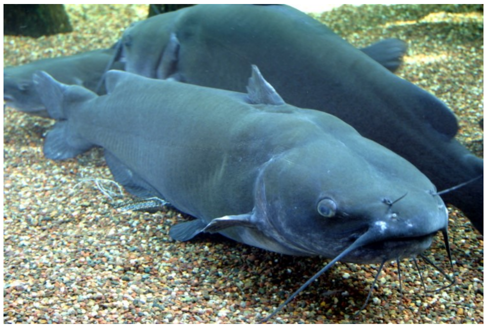
Animal #4

Animal #5

Animal #6

Animal #7

Animal #8



Animal #9

Animal #10

Animal #11

Animal #12

Animal #13

Animal #14

Animal #15

Model Animal

Tab page front

Label: Using Mathematics and Computational Thinking

Using Mathematics and Computational Thinking

Tennessee Academic Standards for Science

Teacher Guide for Grade 2

Standard
2.ESS1.1 Recognize that some of Earth's natural processes are cyclic, while others have a beginning and an end. Some events happen quickly, while others occur slowly over time.

Tennessee Academic Standards for Science: Page 28

Three-dimensional Learning Performance for Lesson
Students will use mathematical and computational thinking* in order to show that some of Earth's natural processes occur quickly and some occur slowly,** highlighting that gradual changes that occur over a large scale of time and fast changes that occur over a small scale of time both have cumulative effects on Earth's variety of surface features.***

Science and Engineering Practice for Lesson
*Using mathematical and computational thinking**
The goal of this three-dimensional learning performance is for students to continue to develop the skill of integrating mathematical and computational thinking into scientific content. It is important to emphasize that students will not be computing any mathematical data during this learning performance; instead, computational thinking will emphasize the relationship between scale, ratios, and natural processes that occur on Earth.

Disciplinary Core Idea for Lesson
*Earth and Space Science 1: The History of Planet Earth***
"Some events on Earth occur in cycles, like day and night, and others have a beginning and an end, like a volcanic eruption. Some events, like an earthquake, also happen very quickly. While others, such as the formation of the Grand Canyon, occur very slowly over a period of time longer than one can observe."

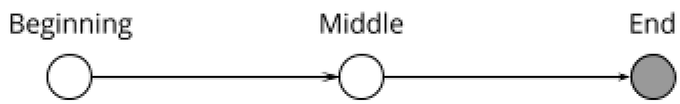
A Framework for K–12 Science Education: Page 178

Crosscutting Concept for Lesson
*Scale, proportion and quantity****
The emphasis of this standard is not on quantitative analysis of time and scale but on the idea that some events can occur slowly and others occur quickly; however, both impact the variety of features seen on Earth's surface. Students will begin to develop the foundational understanding that some events can occur in an observable amount of time, like earthquakes and volcanoes, but other events will occur too slowly to be observed over one's lifetime, like geologic processes. The comparison of these scales is the focus for students at this grade-level, whereas mathematical computation will occur in later grades.

Focusing specifically on fast or slow, hot or cold, etc., will enable young students to gain the understanding necessary to apply this information in more complicated scenarios as they get older.

Prior Knowledge

Location Within Instructional Unit



- Concepts that should be covered before this lesson:
    - Short cycles on Earth (day/night)
    - Fast occurring events (earthquakes, volcanoes)
    - Optional but recommended: in-depth investigations about slower weathering events, such as erosion, deposition, and sedimentation
- This lesson covers portions of standard 2.ESS1.1:
    - Reviews briefly faster events such as earthquakes and volcanic eruptions
    - Reviews briefly slower events of weathering

Materials
- "Weathering and Erosion" article
- Computer/laptop with projector and internet access
- For station rotation activity:
    - Box of 100 sugar cubes
    - Five small disposable aluminum trays
    - Water
    - Small paper cups
    - Five cans of Play-Doh (one for each group of students)
    - Prepared "glaciers" (see station directions below)
        - Ice cube tray
        - Sand, pebbles, sediment
        - Water
    - Twenty wood blocks, such as those found in the game "Jenga"
    - Small plastic beaker (must be transparent)
    - Eight small bags of different colored sand
- Crayons
- Safety goggles
- Sample articles:
    - [Avalance!]
    - [A Grand Old Canyon]

Lesson Sequence and Instructional Notes

"Weathering and Erosion" Article Reading Activity

This article should be a review of all the concepts that have already been covered prior to this lesson. The teacher should engage students by reviewing some of the important vocabulary words and concepts that have been covered up to this point. Then, the students will complete this reading activity that focuses on finding evidence and facts about weathering and erosion. Even though the terms "weathering" and "erosion" appear in the text, you do not need to use these terms exclusively with your students. Using a term like "worn down by water or wind" is sufficient for this grade level. Students will be using crayons to highlight the important parts of the text. It is best to complete this activity as a whole-class reading activity. The whole article is included in this teacher guide, but it was broken up into smaller pieces to assist students with this strategy of identifying the important points within the text. Not every paragraph was included in the student activity.

After the students read along with the teacher and complete the highlighting portion, they have to transfer this information in written form. The same questions that were written in the article are now listed on the next page. Students will copy the answers highlighted in the article onto the lines provided. This will help them practice taking evidence from the text and writing it down.

Accepted Student Responses

1. What type of event happens quickly? (Red) *a fire that starts by a lightning strike*
2. What type of event happens slowly? (Yellow) *rocks are worn down*
3. What are three ways a rock can be carried away? (Green) *moving water, moving ice, wind*
4. When does the ice melt? (Orange) *during warmer weather*
5. How does the ice break off pieces of rock? (Blue) *as the solid ice moves, it breaks off pieces of rock*
6. What moves the broken pieces away? (Purple) *moving ice*
7. What does the wind blow? (Pink) *sand and dirt*
8. What takes a long period of time? (Gray) *the wind wears down rocks*

The teacher should check to make sure each student was able to transfer this information in writing. Emphasis on the scale of time in these answers is important. The teacher can then have students categorize the different types of weathering and erosion by time scale. This would be a good time to reintroduce prior concepts of earthquakes, cycles, and volcanoes. Draw a T-Chart on the board with "Fast" on one side, "Slow" on another, and have students fill in the types of events that fall under each side. Keep this on the board for the duration of the lesson.

- If students are having difficulty coming up with types of events, write out a list of the events covered in this learning performance, and students can discuss them and then categorize them based on the rate of their occurrence.

Expedition Explore!

During this activity, you will be taking your students on a virtual expedition exploring different areas of the United States that show examples of each type of weathering. You will need Google Maps to access this portion of the activity. Using Google Maps, you will be able to explore, move around, and manipulate which portions of the feature you are seeing. For each stop, there are certain questions and details that you should direct the attention of the class to while exploring. Each location exemplifies one or more types of weathering processes. These have all occurred over a long period of time.

Teacher Facilitator Directions
First, open Google Maps and allow it to be projected to the class. Explain to the students that you are going to go on a road trip exploring natural landforms here in the United States that have been formed either by wind, water, glaciers, or depositing rocks. Write these terms on the board so students can continue to refer to this vocabulary. It will be up to the students to decide which location was formed by which process. For each location, the teacher will give a small introduction providing some information about the locality. After exploring the locality, allow students to pair-share for one minute to try to decide which type of weathering is being depicted. After the minute, have students do thumbs up/thumbs down as the teacher reads each word off the board to get a consensus of the class for the answer. The teacher then reveals the answer and explains exactly how the landform was made.

Stop 1—The Grand Canyon:
Located in Arizona, the Grand Canyon is part of a large national park. Students will get to travel down the Colorado River, which runs down the center of the canyon. When on this stop, the teacher should pan the camera up and 360 degrees for students to see all parts of the canyon. Then, you can “kayak” forward and explore different parts along the Colorado River.

Correct Answer: Formed by water (erosion)

Explanation for students: The Grand Canyon was formed over a very long period of time (millions of years) by water constantly wearing down the rocks. The Colorado River is responsible for wearing down these rocks, and it continues to do so even today.

Stop 2—Exit Glacier, Alaska:
Exit Glacier is part of the Kenai Fjords National Park in Alaska. When at this stop, the teacher should point out the glacier, but also focus on the surrounding areas. The deposition of various sediments is obvious at the foot of the glacier as it continues to retreat backward. The teacher should also point out the large scratches and gouges that are obvious on the surrounding boulders and rocks.

Correct Answer: Glaciation

Explanation for students: This process has been occurring at this location and many others over a long period of time. The glacier retreats nearly 200 feet every year since about 2010. The large scratches and gouges in the rocks near the glacier are evidence of the glacier moving and retreating, as the smaller sediments that are trapped in the glacier are scratching the rock as the glacier moves.

Stop 3—Broken Arch, Arches National Park, Moab, Utah:
Arches National Park is filled with many arches that look just like this. This particular arch is called Broken Arch. Direct students to pay attention to its unique shape, and perhaps get students to brainstorm as to why most of the arches in this area look like this.

Correct Answer: Formed by wind (erosion)

Explanation for students: The arches and the surrounding rocks in this area are made up of different types of rocks. Different rocks erode at different rates, with softer rocks eroding faster than harder rocks. These arches are composed of a mix of soft and hard rock, with most of the softer rocks composing what was the middle of these formations. Constant battering by wind and sand in this environment forced the softer rock to erode more quickly than the surrounding harder rock, which is what formed these unique land features. This process takes an extremely long time to complete. Eventually, the arches weaken and will collapse, as many already have within the park.

Stop 4—White Sands National Monument, New Mexico:
The fourth stop on this road trip brings the students to New Mexico. White Sands National Monument looks like a pristine beach in the middle of the state. Even though this is plenty of beautiful, soft, white sand, there is no water in sight. Be sure to tell students this to have them think critically about the formation of this landform. The teacher should also point out the mountains in the distance at this location as a hint.

Correct Answer: Deposition of sediments

Explanation for students: White Sands was formed by the erosion of the gypsum rocks contained in the surrounding mountain region. Wind and water then moved this fine sand to the lower elevation valley, depositing huge dunes of sand. The gypsum sand is incredibly fine and soft. This process is a gradual one, occurring over long periods of time.

Stop 5—Antelope Canyon, Arizona:
Antelope Canyon is different from the Grand Canyon in that Antelope Canyon is below ground, whereas the Grand Canyon is open without a ceiling above it. The teacher should pan the camera in all angles here, taking special note of the sand that forms the path to walk on as well as panning upward, looking at the ceiling of this formation.

Correct Answer: Formed by water (erosion)

Explanation for students: Antelope Canyon was formed by water, specifically large amounts of water. Flash floods quickly erode the Navajo Sandstone that composes the canyon walls, which is why the canyon is “underground.” The large amounts of rain water quickly carve out the rock, creating the lines that you see across the walls and depositing the sand on the bottom of the canyon. Although the flash floods happen very quickly, the overall formation of the canyon is still a long process.

Once you have gone to all five stops, give students about five minutes to reflect their thoughts on their student handout. You can direct students to think about the experience by asking the following guiding questions:

1. What was your favorite location and why?
2. Were all of these formations formed slowly or quickly?
3. Is there a location that you would want to visit?
4. What is the difference between something being formed by water versus wind?

Station Rotations

Students will rotate through five different stations to get hands-on experience in how five different natural processes work and form various landforms. Students will investigate the differences in scale of time through this activity. They will focus on identifying if the process is likely a slow one, taking a long amount of time, or one that occurs very quickly.

Split students up into groups of three to five individuals. Each station will have a specific set of directions for students to follow to complete each activity. Each investigation is small and short. Students will complete the table in their student handout at each station. They are asked to draw a picture of what they did, write an explanation, identify the type of weathering process, and identify the scale of time likely needed to complete the process and change the surface of the Earth. Below is a general outline of each station and the materials needed, but refer to the *Student Directions Guide* for the printable directions for each station. Words that students will need to know to fill in the “type” column: Formed by wind, water, ice, volcano, and earthquake.

Station 1: Erosion of Rocks

The materials needed for this station will be a disposable aluminum tray, sugar cubes, cups, and water. Students will get to build a small structure out of sugar cubes (10 cubes per group) and use the cup to slowly pour water on the sugar cubes. They will then make observations about what is occurring as the water passes over the cubes, and in the short time after the water is poured.

Correct Student Response: “Slow Process.” Students should see the sugar cubes begin to break up and “erode” as the water passes over them. Cubes that were not touched by the water will not change. Their explanation should include that the amount of water needed to change the rocks would be large, and it would take a long time to accumulate that kind of change. Students may even witness the deposition of the broken sugar cubes at the bottom of their tray.

Station 2: Glaciation
You will need to prepare the ice cubes two nights before teaching this lesson. Simply take sediment that contains small pebbles, rocks, sand, etc. and fill each well in an ice cube tray just above half. Then add water and freeze for two days to form mini-glaciers. Students will take one mini-glacier and slowly run it over a flattened piece of clay.

Correct Student Response: “Slow Process.” They will get to see the impressions that are made in the clay, but also watch as the ice cube melts. It will deposit the sediments as it is slowly moved down the clay. Students will then leave the glacier in the middle of the clay and let it melt.

https://betterlesson.com/lesson/resource/3227529/glacier-ice-cube

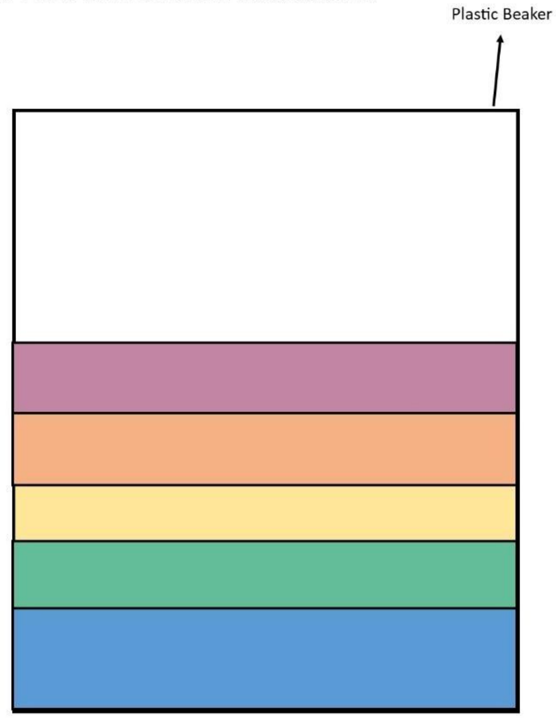
Station 3: Earthquake
Students will use the wood blocks provided to build a tower. Then, an earthquake will strike! The teacher (or a selected student) will then shake the table.

Correct Student Response: “Fast Process.” Students will witness their “building” collapse as the table is shook. Students should reason that an earthquake comes quickly, ends quickly, and quickly changes the landscape by collapsing both human-made structures as well as natural ones.

Station 4 : Sedimentation and Wind Erosion
At this station, students will use the small plastic cups to scoop one color of sand and add it to the beaker. The teacher will have already placed three layers of different colored sand in the beaker before the activity was started. Each group, as they rotate, will add a different colored layer. At the end of all of the rotations, students can see the final product. This

station demonstrates the idea of sedimentation, or when sediment is placed down in layers over time. Then, have students put on safety goggles and have one student blow the top layer of sand and record what happens. Each student can take a turn blowing the sand. Correct Student Response: "Slow Process." Students will get to see that sediments are usually laid down in layers, and although one layer may be laid down quickly, the overall landform will take time to be made (this is demonstrated by each group rotating through and adding a layer). See the model below for clarification. Students should then be able to identify the impact of "wind" on the way the top layer looks. They may even be able to expose the layer underneath, depending on how much sand was added.

Model of Sedimentation Station—Plastic Beaker Filled with Different Colored Sand



Station 5: Eruption
At this station, students will watch a video of the recent volcanic eruption in Philippines (January 2018)—[linked here](). This is a time lapse video, so it has sped up the actual event.

Correct Student Response: "Fast Process." Students will come to the conclusion that the lava that is released from the volcano will have a rapid and immediate effect on the surrounding area. The ash that is released from the eruption will also settle all around the volcano, again, drastically changing the landscape.

Once students have completed the rotations, the teacher may choose to collect the work to determine student understanding or go over the answers together as a class. During the rotations, the teacher should be facilitating important discussions between students within a group to help guide them to the correct answer. Some helpful questions are listed below to engage students in productive conversations.

- What observations can you make about this event?
- Since these are scaled down versions, how does this compare to the real thing?
- How does this event compare to _________ (insert different station) event?
- How would this event change the landscape of the surrounding environment?

Formative Assessment Scenario : Identify Pictures

Task

Present students with recorded observations of the natural world, and ask them to describe a pattern or relationship that can be inferred (STEM teaching tool #30).

The task presented above is for the practice of analyzing and interpreting data, but this is an important skill to build the foundation needed for thinking computationally. Students are not required to analyze information quantitatively, and so the focus is on students being able to analyze pictures, draw evidence, and think about the scale of time that it takes for each event presented to occur.

Students are presented with pictures of different stages of weathering, erosion, deposition, and other natural disasters. Students should work individually on this portion. They will need to identify the type of event and the time that it took to occur (fast or slow).

Correct Student Responses

Problem Number	Picture	Scale of Time	Type of Event?
1		Slow	Formed by wind

2		Slow	Formed by ice
3		Slow	Formed by water
4		Fast	Volcano
5		Slow	Formed by water
6		Fast	Earthquake

Formative Assessment Scenario 2: Text-based Approach

Task

Present students with a textual description, and ask students to draw grade-level appropriate conclusions. (STEM teaching tool #30)

In this scenario, students will be comparing two different texts about the formation of two different landforms. The first, the Grand Canyon, has been forming for millions of years and is representing the “slow” formation. The second text is about an avalanche, which is representing the “fast” alteration to Earth's surface. The focus on these texts is to demonstrate the difference in the scale of time between both events.

Students have been given a concept map for both texts. The teacher should read the articles with students and assist them in filling in the charts. One suggestion is to read the articles the first time out loud with the students, then have students work in pairs to read it again and fill out the concept map together. Another suggestion could be to project the concept map up on the board and fill it out as a class. If students are working in pairs, it is recommended that they only work on the concept map portion together but answer the questions individually, so the teacher may gauge individual student understanding and mastery of the content. Students should use their concept maps and the text to complete the questions. The teacher should encourage students to use evidence from the text to complete their answers.

Teacher Evaluation Notes

Question 1:

- *Full Understanding*: A student with a full understanding of the reading and the content will answer the question correctly and identify the avalanche as the event that occurs quickly. They will also be able to provide evidence from the text, such as the statement of “occurs suddenly” to support their answer.
- *Partial Understanding:* A student with partial understanding will be able to correctly identify the avalanche as occurring quickly but will lack any evidence from the text.
- *Limited Understanding:* A student may not be able to identify which event occurs quickly. This could be due to a lack of understanding of the content, inability to comprehend reading content, or a combination of both.

Question 2:

- *Full Understanding:* A student with a full understanding will be able to draw the conclusion that avalanches occur quickly while glacial movements occur slowly. They may reference the lab, prior lesson practice, or the texts used in this lesson to come to this conclusion. Students with a full understanding may also identify different impacts the two events have on the landscape. Specifically, the glacier moves rock and sand and can scratch or break up

rock, whereas an avalanche occurs so quickly that it covers the landscape with deep snow, breaking trees and structures instead of moving them.
- *Partial Understanding:* A student may be able to correctly identify the difference in the scale of time, indicating that glaciers are a slow process but avalanches occur very quickly. They will not reference the difference in the impact on the landscape.
- *Limited Understanding:* A student with a limited understanding would not identify the different in the scale of time, but instead talk about superficial physical differences between an avalanche and a glacier.

Question 3:
- *Full Understanding:* A student with a full understanding would be able to explain that the Grand Canyon is very big and deep, so it would have taken a long time to form. They may reference the text and provide evidence in the actual time it took (millions of years) and again reference how the canyon was formed (all gathered from the reading).
- *Partial Understanding:* A student with partial understanding may not be able to clearly explain and draw a parallel between time and size of the canyon. They may provide information from the text about the time it took (millions of years) and how it was formed since this information is directly available to them.
- *Limited Understanding:* A student will not be able to make the connection between time and size of the canyon.

Question 4:
- *Full Understanding:* This question is the mastery question for this lesson plan. The objective of this lesson was to get students to be able to distinguish between short and long periods of time in the formation of Earth's features, as well as compare fast and slow events directly. Students with a full understanding will be able to make a direct comparison, stating that the Grand Canyon was a slow process that took a long time to form, whereas the avalanche is a fast process that occurs over a short period of time. They will use evidence from the texts to support their answer.
- *Partial Understanding:* Students may be able to identify that the Grand Canyon took a long time to form, whereas the avalanche occurred quickly; however, they may not be able to clarify the computational thinking portion of this lesson by comparing time scale (fast and short amount of time vs. long and occurring slowly).
- *Limited Understanding:* Students will not be able to make a direct comparison and may not be able to correctly identify the time or length of time it took to form either of the processes. Potentially, only one event is addressed correctly or incorrectly in a limited response.

Citations and Resources

"A Grand Old Canyon" by Linda Ruggieri from Readworks.org

"Avalanche!" by Rachelle Kreisman from Readworks.org

"Weather and Erosion" by Rachelle Kreisman from Readworks.org

Glacier station activity adapted from "How Do Glaciers Change the Shape of the Land" lesson written by Jeri Faber. Betterlessons.org

Fast or Slow?

Deciding the time scale of different natural processes that shape Earth’s features

Weathering and Erosion

by Rachelle Kreisman

Nature is always changing. Those changes are called natural events. Some natural events happen quickly. Think of a fire that starts when lightning strikes a tree. Other events occur slowly, such as when rocks are worn down over hundreds of years. This happens because of weathering and erosion.

What type of event happens quickly?

What type of event happens slowly?

Weathering is what happens when a part of a rock is loosened. Parts of rocks are usually loosened by nature. Erosion (ih-ROH-jzun) happens after weathering. It is the process of moving water, moving ice, or wind carrying away a part of a rock.

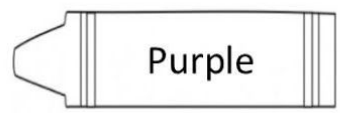
What are the three ways a rock can be carried away?

Moving ice can cause weathering and erosion. Some mountains have solid sheets of ice near the top. During warmer weather, a bit of ice melts. Then the sheet of ice may move slowly down the mountain. As the solid ice moves, it scrapes rocks, breaking off pieces. Then the pieces are taken away by the moving ice.

When does the ice melt?

How does the ice break off pieces of rock?

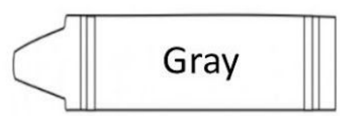
What moves the broken pieces away?



Wind also causes weathering and erosion. Wind can blow sand and dirt. It can carry the dirt far away. In some places, strong wind will push sand against rocks. Over a long period of time, the wind wears down those rocks.

What does the wind blow?

What takes a long period of time?



Article adapted from “Weathering and Erosion” by Rachel Kreisman from Readworks.org

Answer the questions again, but, this time, write the answers instead of highlighting them.

1. What type of event happens quickly? (Red)

2. What type of event happens slowly? (Yellow)

3. What are three ways a rock can be carried away? (Green)

4. When does the ice melt? (Orange)

5. How does the ice break off pieces of rock? (Blue)

6. What moves the broken pieces away? (Purple)

7. What does the wind blow? (Pink)

8. What takes a long period of time? (Gray)

Station Rotation Activity – Fill in the answers for each station below.

Station Number	Picture	Explanation	Type?	Fast or Slow?
1				
2				
3				
4				
5				

1. Identify the pictures below as being made by wind, water, ice, or as the result of an earthquake or volcano. Then, write whether the process is fast or slow.

Word Bank for Type of Event

Earthquake
Formed by Wind
Volcano
Formed by Water
Formed by Ice

Problem Number	**Picture**	**Scale of Time (Fast or Slow)**	**Type of Event?**
1	 https://en.wikipedia.org/wiki/Hoodoo_(geology)		
2	 https://www.nps.gov/mora/learn/kidsyouth/index.htm		
3			

4	 https://www.nps.gov/havo/planyourvisit/lava2.htm		
5	 Jim Bain; geography.org.uk		
6	 https://commons.wikimedia.org/wiki/File:Haiti_earthquake_damage.jpg		

2. For each reading, fill out the concept maps below. Then, answer the questions based on the information you read in the story.

Text #1 The Grand Canyon	Text #2 Avalanche!
MAIN IDEA	MAIN IDEA
How was it formed?	How was it formed?
How long did it take?	How long did it take?

Questions:

1. Which event, the formation of the Grand Canyon or the avalanche, occurred quickly? How do you know?

2. How is an avalanche different from a land feature formed by a glacier?

3. Why do you think the Grand Canyon took so long to form?

4. How does the time it took for the avalanche to occur compare to the time it took the Grand Canyon to form?

Station 1: Erosion of Rocks

Directions:

1. Place the aluminum tray in the middle of the table.
2. Count out 10 sugar cubes.
3. Place the sugar cubes in the tray however you want (they should all be touching).
4. Fill your small cup with water.
5. Slowly pour the water directly on the sugar cubes.
6. Observe what happens!

Station 2: Glaciation

Directions:

1. Take the “glacier” ice cube from the tray.
2. Flatten out one piece of clay on your desk.
3. Starting at one end, slide the ice cube (dirty side down) slowly across the clay.
4. Stop halfway down the clay. Leave the ice cube there to melt.
5. Observe what happens!

Station 3: Earthquake

Directions:

1. Build the blocks into a tower or house in the middle of the table.
2. Draw what the tower looks like.
3. Have one student shake the table as hard as they can.
4. Observe what happens!
5. Draw the after picture.

Station 4: Sedimentation and Wind Erosion

Directions:

1. Choose a color of sand that has not yet been used.
2. Scoop the sand up in your small cup.
3. Gently and carefully pour your sand into the container on the desk. Be sure not to disturb any other sand layers!
4. Put on your safety goggles!
5. Take turns blowing the layer of sand you just added.
6. Observe what happens!

Station 5: Eruption!

Directions:

1. Watch the video that is pulled up on the computer.
2. Talk with your group about how it might impact the area around the volcano.
3. Draw a picture on your handout.
4. Fill out the rest of your table!

Tab page front

Label: Constructing Explanations and Designing Solutions

Constructing Explanations and Designing Solutions

Tennessee Academic Standards for Science

Teacher Guide for Grade 2

Standard
2.ESS2.2 Observe and analyze how blowing wind and flowing water can move Earth's materials (soil, rocks) from one place to another, changing the shape of a landform and affecting the habitats of living things.

Tennessee Academic Standards for Science: Page 28

Three-dimensional Learning Performance for Lesson
Students will construct an explanation[*] in order to show that blowing wind and flowing water can change Earth's landforms and affect habitats of living organisms[**] highlighting that these changes occur as part of a natural system of Earth's processes.[***]

Science and Engineering Practice for Lesson
Constructing Explanations[*]
The goal of this three-dimensional learning performance is for students to begin building a foundation of how systems on Earth interact and cause changes to landforms over time. These changes have contributed to the diversity of habitats and the organisms that inhabit them. Students will explore how wind and water can maintain or change these landforms and the resulting impact on animal inhabitation. Explanations will be constructed with evidence from various sources, including maps, grade-level texts, documentaries, and modeling. Students will be able to practice the important scientific skill of gathering information from various sources and compiling the information into one, well-constructed explanation.

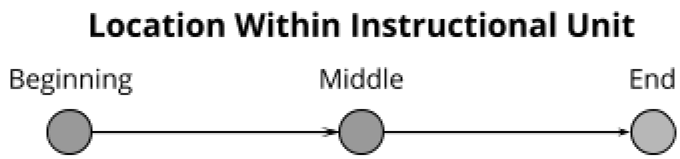
Disciplinary Core Idea for Lesson
Earth and Space Science 2: Earth's Materials and Systems[**]
"Earth's surface is a complex and dynamic set of interconnected systems – principally the geosphere, hydrosphere, atmosphere, and biosphere – that interact over a wide range of temporal and spatial scales. All of Earth's processes are the result of energy flowing and matter cycling within and among these systems."

A Framework for K–12 Science Education: Page 179

Crosscutting Concept for Lesson
Systems and System Models[***]
When students make associations between the movement of Earth's materials via wind and water and the direct impact of this movement on animal habitats, they begin to build a deeper understanding of the connection between non-living and living things. The

movement of these materials by these systems are instrumental in maintaining landform and organismal diversity.

Prior Knowledge



- Concepts that should be covered before this lesson:
    - Wind, water, and ice weathering and erosion (2.ESS1.1)
- This lesson covers all portions of standard 2.ESS2.2

Materials

- Computer with internet access and projector
- Video links (optional)
    - "Inside the Mangrove Forests"
    - BBC's Planet Earth, episode 5, "Deserts"
- Construction paper
- Crayons, markers, colored pencils
- Scissors
- Rulers
- Post-it Notes (three different colors)
- Chart paper
- *Student Guide*, one copy per student
- "The Mangrove Forests" article
- "The Sahara Desert" article
- *Final Project Template*, one copy per student
- *Final Project Rubric*

Lesson Sequence and Instructional Notes

Teacher Introduction

This lesson approaches the standard with comparative case studies of two localities that demonstrate the standard. The Sahara Desert, located in Africa, is one of the largest deserts in the world. It is the size of the United States and has been formed for millions of years by wind. In contrast, the Mangrove Forests of India help prevent river bank erosion, an essential effort for conservation of this unique habitat. River bank erosion is a common problem, and humans work tirelessly to try to prevent it. The mangrove trees are a natural bank stabilizer and provide a unique habitat for many animals. These two examples highlight this Earth science standard and will provide students with real-world examples.

Students will move through the various parts of this lesson, gaining new information about these two localities in a variety of ways. At the end, students will create a book for preschool aged children about one of the case studies and construct a final explanation of how these areas are formed and about the habitats they provide for some example animals. Each step and activity are going to provide a page of information that students will want to include in their final book. This lesson is set up more as an exploration of these two landforms, where students are going to be gathering information on their student handout, and then will use this to compile a final constructed explanation to teach other children about their chosen location.

Student Introduction

Students will be introduced to these two locations by evaluating pictures on their student handout. First, students will write down any descriptors they notice in the two different pictures. Then, they will hypothesize about which one was formed by water and which one was formed by wind. It is important for students to give a brief explanation supporting their answer. When all students have completed these on their own, the teacher will go over them. It is recommended that the teacher project the pictures and tables (this will also enable students to see the pictures in color) on the board and fill in the table with student responses. After the table is completed, the teacher will assign the name of "Sahara Desert" to the first picture and the name "Mangrove Forest" to the second.

It is important to remember that this standard is focusing on the mechanism for how these habitats are formed, and less about the habitats themselves. Since the term "habitat" has not officially been introduced to students by this point, it may be beneficial for the teacher to review the information presented in 2.LS2.1 and 2.LS2.2, as these imply "habitats" without using the actual vocabulary term. Students should be able to make the connection between the content that was presented in 2.LS2.1 (how animals depend on their surroundings for survival) and the term "habitat" as a place where certain animals live.

Mapping Activity

Once students have been introduced to both habitats, they will identify the location of these on a map. This is an important factor in the students understanding the relationship between these two places. The teacher will simply instruct the students which areas to color on the map. The Sahara Desert has been marked in Africa with lines as borders. Have students color this portion of their map in with an orange crayon. Then, have students color in the whole subcontinent of India with a green crayon. Below are some guiding questions that teachers should ask students to encourage them to make connections between the locations of these habitats and the pictures they looked at earlier.

- Are they close or far away from where we live in Tennessee?
- Where do you think the sand comes from for the Sahara Desert?

- Where is the ocean in relation to India (this is meant for students to connect that India is a coastal location vs. the mostly landlocked desert)?

The teacher will want to project the Google Maps interactive image of the Sahara Desert for students while the map activity is being discussed. Students will be able to see how different the desert looks in comparison to the surrounding regions. Use this link to access the interactive Google Maps website.

In contrast, the Google Maps satellite images of India are very different. India is shown as green since it is covered in forests. Have students look specifically at the west coast of India where the green is deeper in color. This is the location of some of the Mangrove Forests, although the forests really surround a large part of the coastal portion of India. Here is the Google Maps link for the continent of India.

Multimedia Focus

Now that students understand where these two locations are, students will get to watch two videos that show more information about these areas. The purpose of these videos is (1) to demonstrate the role that wind plays in formation of sand dunes in the desert, (2) to demonstrate the rise and fall of the water and the impact on the Mangrove Forests, and (3) to highlight some of the animals that inhabitant these unique formations. It is recommended that the teacher pause and reinforce the important parts of the video. In the desert video, the teacher should be reinforcing the role the wind is playing in the formation of the dunes and how the wind is moving the sand from one place to another. For the mangrove video, the teacher should pause and highlight how the rising tides and ocean current impact this area and how the mangroves reduce flooding and coastal erosion.

Students will be able to identify two animals that live in each habitat. Highlighting the animals that live there addresses the organismal diversity portion of the standard. Some animals that are highlighted in the videos are only found in these unique habitats. Not a large amount of time will be spent on the animals, because they are not a specified in this standard; however, it is important for students to understand these processes and their impact on the whole system, which includes the organismal diversity.

"Inside the Mangrove Forests"

End video at 2:38 seconds

BBC's Planet Earth, episode 5, "Deserts"

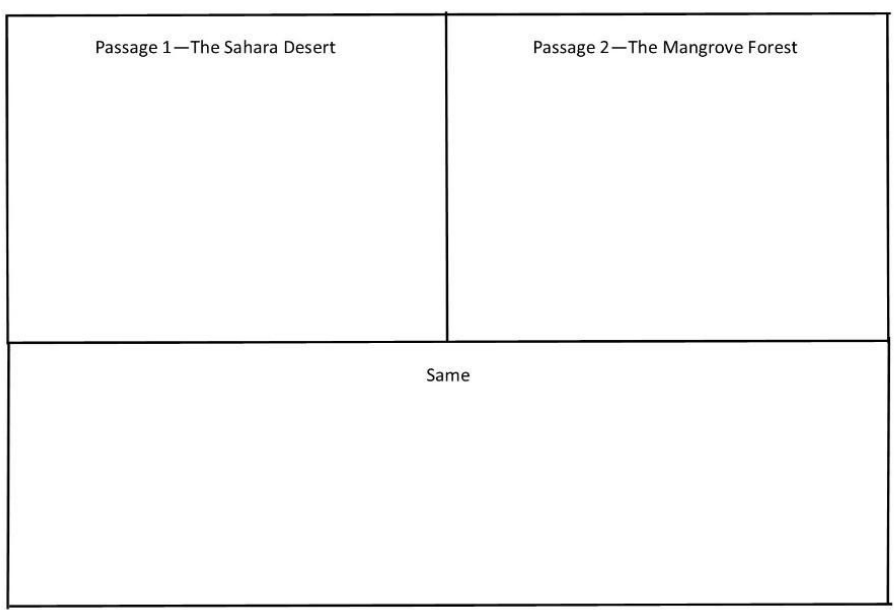
Start video at 6:30 seconds and end at 8:23 minutes for the Sahara Desert. However, continue on for a few more minutes to hear more about dunes in a different desert. Due to potential school firewalls, it is recommended to download the video at home onto a travel drive or computer, then show the video in class.

Text Analysis

For this portion of the activity, students will compare two nonfiction texts about the Sahara Desert and the Mangrove Forest. Students will get to write facts from the readings onto Post-it Notes and place them on chart paper to organize the information from both texts. Having a visual of the facts up on a piece of chart paper will also help students directly compare and contrast these two areas. Then, students will get to try constructing an explanation based on the information they have gotten from the text. This is the first time in the lesson students will get to experience working with the scientific practice, but they will be able to get more preparation in writing an explanation from each activity hereafter.

Reading Directions
On chart paper or on the whiteboard, copy the diagram that is shown below. Explain to students that they are going to read two passages, one about the Sahara Desert and one about the Mangrove Forests. Once the passages are read, the teacher can explain to the class that they will identify important facts from each passage and then write them on post-it notes to post onto the chart. Assign a different color Post-it Note to each passage, and then a third color to the "Same" category on the chart.

Model for Post-It Note Activity



The teacher should read one text aloud and have students actively listen and follow along. Then, the teacher can read the second text. After one reading, the teacher can break students up into groups of two or three individuals. Groups will now read the text together and try to identify important facts in the passage. Depending on the population of students, the teacher may choose to assign one article to each group, so that both articles are being covered by different groups at the same time. Or, the teacher can have every group work on both articles.

Once students have identified the facts from the passage, they can copy the facts down onto their student handout, and then transfer the facts onto Post-it Notes. Once all groups have their facts written on the notes, they can come up and place them in the appropriate parts of the chart. So that each group can contribute, the teacher may want to only have one Post-it Note from each group. Once all the notes have been placed, have students read their fact out to the class. The teacher will then review the information with the class. Students should be trying to recognize any similarities or patterns between the two locations, so they can also add Post-it Notes to the "Same" column. It is suggested the teacher leaves this chart up for the duration of this lesson, so students can continue to refer back to the facts that they may not have written down themselves.

At the end of the activity, give students about five minutes to construct an explanation about how these landforms are made. Students, up until this point, have been focusing on analyzing and observing the process of formation, but now they will have to explicitly explain it in their own writing. The prompt for students to write their explanation is on their student handout. The explanation should restate the prompt and provide evidence from the text supporting their answer.

Teacher Evaluation of Responses

Formation of Sand Dunes

- *Full Understanding*: Students with a full understanding will be able to indicate "sand dunes in the Sahara Desert are formed when wind blows and moves pieces of sand into a pile."
- *Partial Understanding*: Students with a partial understanding will be able to indicate "sand dunes are formed by the wind blowing sand."
- *Limited Understanding:* Students with an incomplete or limited understanding may not be able to find the correct answer in the text. The teacher may have to help facilitate the student to find the information and formulate the answer into a sentence. A student with limited understanding may respond with "wind" or "blowing sand" as the only words in the answer.

Erosion of mangroves

- *Full Understanding*: Students with a full understanding will be able to indicate "the mangrove trees and roots help to keep the dirt and rocks from being swept away by the water."
- *Partial Understanding*: Students with a partial understanding will be able to indicate "the mangroves stop the riverbank from wearing away."
- *Limited Understanding:* Students with an incomplete or limited understanding may not be able to find the answer in the text. Or, if they do, they may just

copy “stops the riverbank from wearing away” directly from the text but lack the comprehension of what this means.

Modeling the Process

Since this standard focuses primarily on the role that wind and water play in the formation of landforms on Earth’s surface, students should be able to distinctly identify this process and how it plays into the natural system of Earth. Students may struggle with this portion, but it is important for them to apply what they have already learned about these two localities and try to apply it in a way to figure out this challenge.

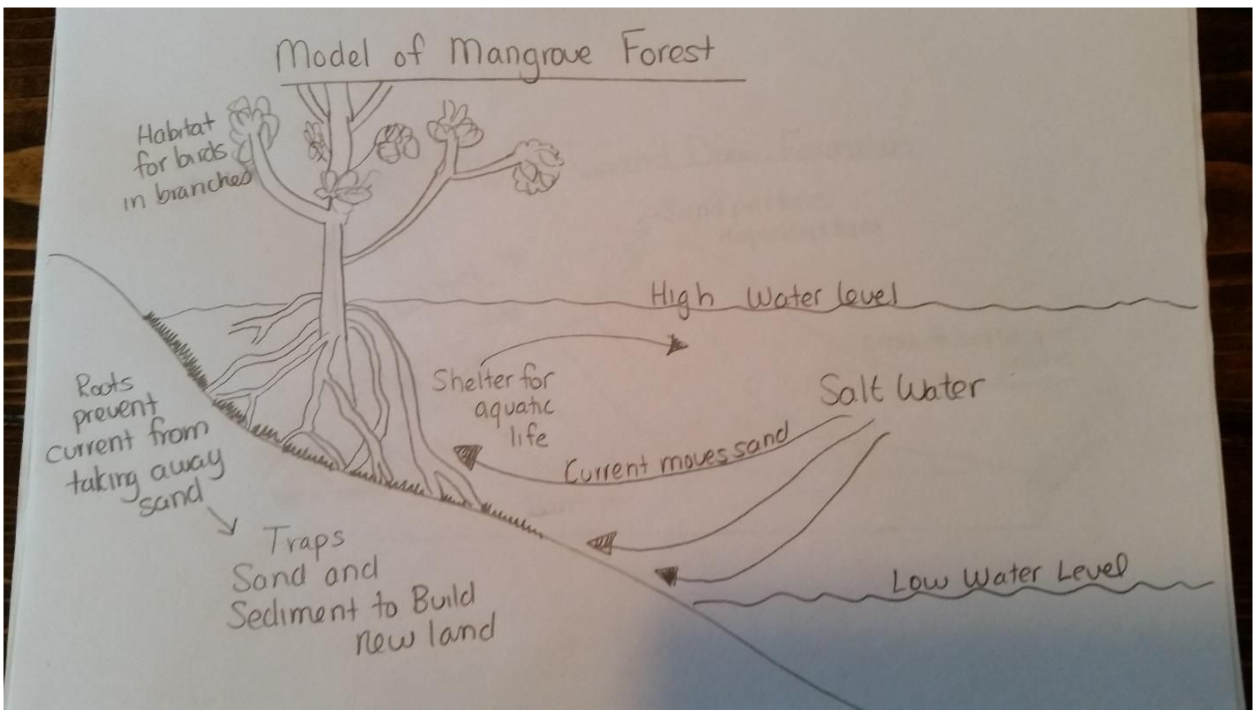
The teacher should review how sand dunes are formed and how the Mangrove Forests help prevents the wearing down of a river bank. (If the information provided by the student texts is not enough and the teacher still seeks additional content information, then please see the two resources listed in the citations and resources section of this guide.) Then, simply ask students to draw a picture showing this process. Have them attempt this individually at first, giving students about five to eight minutes to complete it. Encourage students who are struggling or are not confident on how to depict this information. Students should attempt to model this process with only facilitation from the teacher. Inform students that it is okay if their model is not completely correct. The teacher should be walking around and ensuring that each student is attempting this challenge. Once each student has a picture, ask students to partner up and compare their models for both locations. Encourage students to participate in a conversation of explaining their model and the decisions that they made when drawing it. Have a few pairs share their model with the class by drawing their models on the board or a couple of pieces of chart paper around the room.

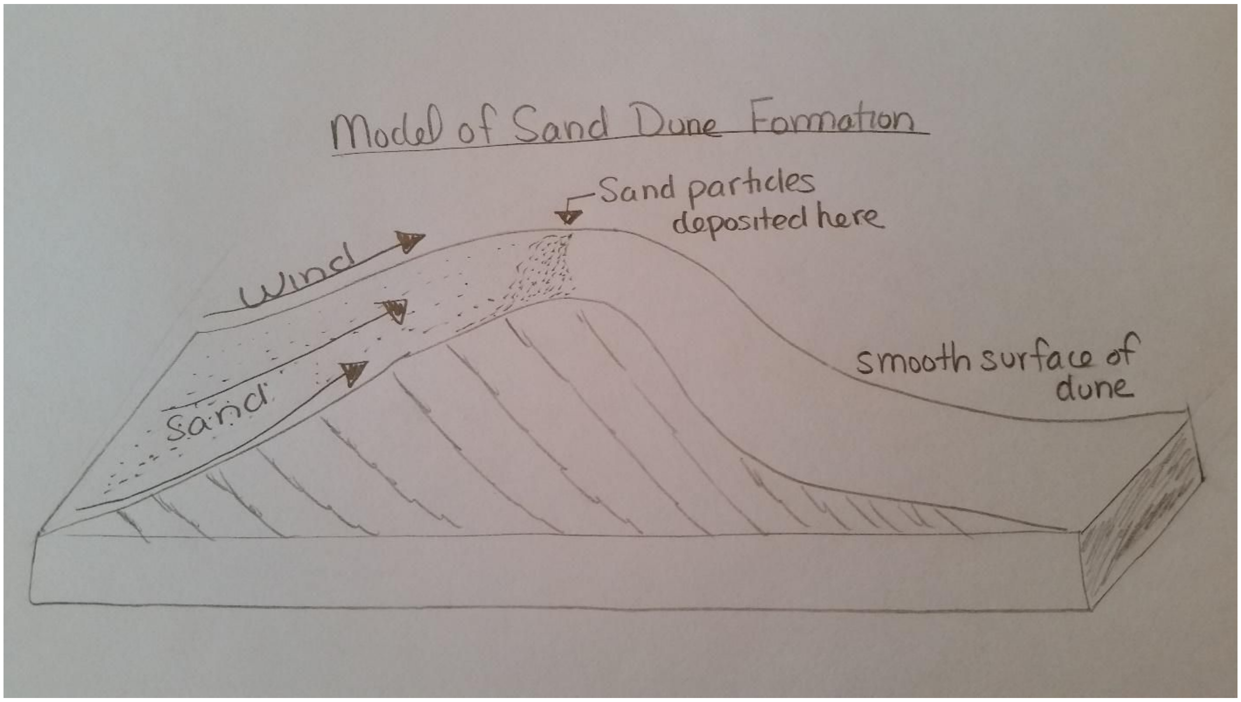
Give each student one Post-it Note (leftover from the previous activity). Allow students to get up and view the drawn models. Inform them to use the Post-it Note to point out one thing they like about one of the models that is drawn. Encourage students to pick out something that is correctly drawn or identified. They should only be placing positive notes at this time. Once every student has posted a note, hand each student a different colored Post-it Note, and then tell them they will be writing one critique. The critiques should be phrased “I wonder if…,” so they still carry a positive tone. For example, a student may write “I wonder if you draw an arrow here instead of there, if it would make the picture better.” If the teacher feels the students are unable to appropriately complete the second portion, it can be omitted. Once all notes have been posted, hold a discussion with the group about the best portions from each model. The responses should be enough that the teacher can draw a final, correct model on the board for students to see. A correct model for each process is shown on the following page.

Students will then construct an explanation on how these processes can change the shape of the landform. Specifically, students should be able to identify that the dunes actually move and also change in shape and size, because the wind continues to blow the sand off of them and around them. For the Mangrove Forests, students should be able to focus on the rising and falling levels of the water and how that may move sediment in and out of the roots of the trees, changing the landscape under the water.

Note: Students may struggle with the mangrove model. The correct models depicted below are for teacher information; students may not generate pictures that look exactly like these. Modify the ones shown below to best represent the work that is being completed by students in the classroom. Be sure to assist students to have all important vocabulary terms and points of each model, but they can look different and still be accepted as correct. Models will vary between classrooms and students.

Correct Model of Processes





How Wind or Water Shapes Animal Habitats Book

Task
Describe a phenomenon to students along with relevant evidence then ask students to write an evidence-based account of what causes the phenomena (STEM Tool #30).

Now that students have gathered information about each location from various sources, they will get to choose which habitat they will make a book about. They will use construction paper stapled together to form a book. The information that should be contained within the book and on each specific page is listed below. Instruct students that they will be compiling all of the information they learned over the past couple of activities into one book. The book should be written to teach their younger siblings or family members or students about the area they chose. This can be an in-class project or can be worked on at home, based on the population of your classroom.

- Page 1: Title page. This should include the title of their book ("How Wind/Water Shapes Animal Habitats:), a drawn picture of their choice (related to the activity), and their name.
- Page 2: Table of contents. This should include all of the pages and page numbers of the content of the book.
- Page 3: Landform location. They can copy the map, draw a new one, or just write a description.
- Page 4: Description/About page. Students can include information from the video or the text that describes their location. This can include information about the area, a description of what is found there, or what it looks like.

- Page 5: Formation focus. For the desert book, this page should focus on the dunes. For the mangroves, it should focus on the tree roots. A drawn picture of the formation should be included.
- Page 6: How it's formed. This page should focus on how the formation from Page 5 is actually formed. Wind and water should be the highlights. The model that was drawn in prior activities should be included, as well as the constructed explanations that were made from during the text activity AND the model activity.
- Page 6: Animal homes. This page can highlight the animals that were described in the video. Students already picked two animals to write about, and this is where they can put that information as well as draw pictures. Students will also need to include a constructed explanation as to how the formation provides shelter and resources to the animals.
- Page 7: Summary page. This is where students will construct a final, comprehensive explanation of how wind and water play a role in the formation of these landforms, which then act as homes for a diversity of animals. This is the final formative assessment for this lesson, where a majority of points will be allotted in the rubric for grading.

Citations and Resources

Information about Mangrove Forests:
Spalding M, McIvor A, Tonneijck FH, Tol S and van Eijk P (2014) Mangroves for coastal defence. Guidelines for coastal managers & policy makers. Published by Wetlands International and The Nature Conservancy. 42 p

https://www.nature.org/media/oceansandcoasts/mangroves-for-coastal-defence.pdf

Information about Sand Dunes:
Rutledge K, McDaniel M, et al. “Dunes” from National Geographic Pages. Accessed March 1, 2018.
https://www.nationalgeographic.org/encyclopedia/dune/

A Tale of Two Landforms

The Sahara Desert and the Mangrove Forests of India

1. Wind and water can change the shape and look of Earth's surface. This happens as a system of natural processes and is important for animals and their habitats (places they live).

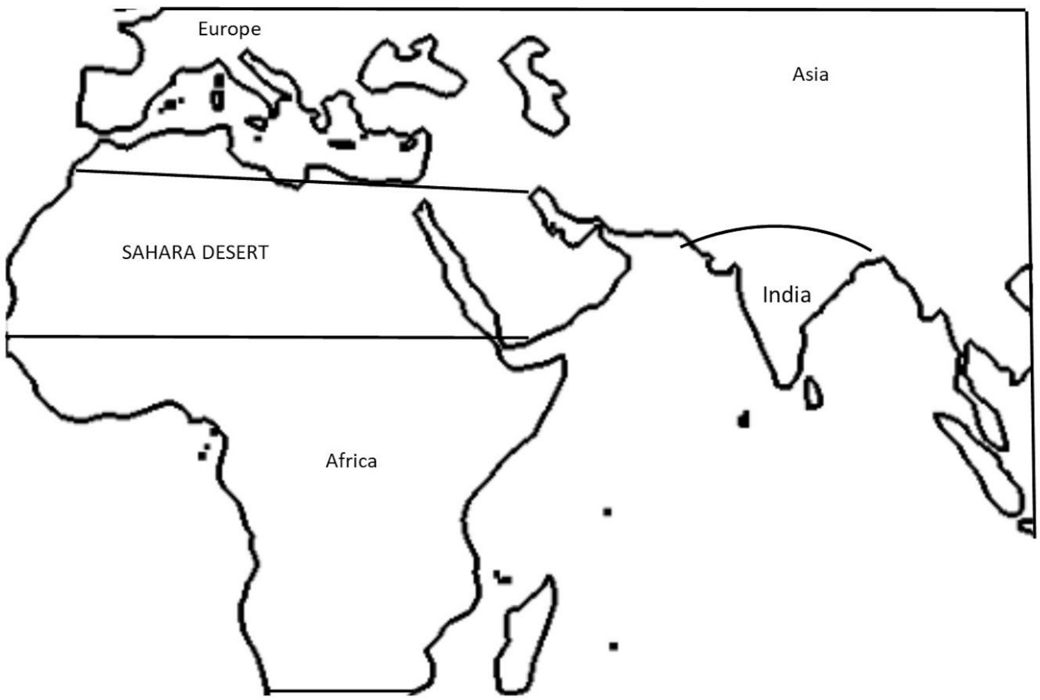
Look at the two pictures below.

- Which do you think is a desert and which picture looks like a forest?
- Can you describe each one?
- How do you think they were formed?

Location #1	**Location #2**
 https://www.flickr.com/photos/wonker/4300437105	 https://www.flickr.com/photos/ashwinkumar/6066501103
What does it look like?	What does it look like?
Wind or Water? Why do you think that?	Wind or Water? Why do you think that?
Name:	Name:

2. On the map below, color the Saharan Desert orange, and the country of India green.

MAP OF AFRICA AND ASIA



3. Animals of the Sahara and Mangrove Forests

Watch the videos about the Sahara Desert and the Mangrove Forests. Pick out two animals from each video and write about them below:

The Sahara Desert	**The Mangrove Forests**
Animal 1:	Animal 1:
Animal 2:	Animal 2:

4. A Tale of Two Texts

After reading each text, write down the facts you and your group have found in the space provided below.

The Sahara Desert

- Fact #1
  ____
  ____
  ______________________________.
- Fact #2
  ____
  ____
  ______________________________.
- Fact #3
  ____
  ____
  ______________________________.
- Fact #4
  ____
  ____
  ______________________________.
- Fact #5
  ____
  ____
  ______________________________.

The Mangrove Forest

- Fact #1
  ____
  ____
  ______________________________.
- Fact #2
  ____
  ____
  ______________________________.
- Fact #3
  ____
  ____
  ______________________________.

- Fact #4

  ____
  ____
  ____.
- Fact #5

  ____
  ____
  ____.

Construct an explanation as to how sand dunes are formed, based on the information in the passage:

____
____
____.

Construct an explanation as to how the mangrove trees help protect the riverbank from wearing away from rising and falling water levels.

____
____
____.

5. Model the process!

In the box below, draw a picture that shows how a sand dune is formed in the desert. Be sure to label what you drew (you should label sand, wind, and dune). Your drawing should have at least one arrow.

What is one thing you liked about someone else's model?

____
____
____.

Now, construct an explanation on how you think the wind can change the shape or size of the dunes.

____
____
____.

In the box below, draw a picture that shows how, when the water rises and falls, it can move rocks and sand under the water in the Mangrove Forests. Be sure to label what you drew (you should label roots, mangrove, water, sand, and rocks). Your drawing should have at least one arrow.

What is one thing you liked about someone else's model?

____
____
____.

Now, construct an explanation on how you think the water can change the amount of sand and rocks that are found under the mangroves.

____
____
____.

THE MANGROVE FORESTS

Leon Petrosyan

ABOUT THE FOREST

Mangrove forests grow in coastal areas. These trees are special because they grow in salty water. These forests are found in India, Asia, and even in Florida!

Hillebrand Steve

RIVER BANK

Mangrove forests have important jobs. They prevent the river bank from wearing away by the rising tides and waves. The water they live in helps to form this special landform. Without the mangroves, the river bank would wear away.

Vanisiri874

LIFE IN THE ROOTS

Many animals call the mangroves home, including birds, fish, snakes, and even tigers! Some animals are only found here in the mangrove forests. They make their homes in the long roots that stretch deep into the water.

THE SAHARA DESERT

ABOUT THIS DESERT

The Sahara Desert is found in Northern Africa. It is the third largest desert. The Sahara is a very hot desert and less than 3 inches of rain falls each year.

SAND DUNES

Deserts are characterized by having sand dunes. Sand dunes are tall piles of sand that are formed by the wind blowing small pieces of sand into a pile. The size of the dunes are constantly changing with the wind.

You can see in the picture above how the wind can make waves in the sand. The wind is very important for forming the features of the desert.

https://www.flickr.com/photos/paulspace/7071640051

LIFE IN THE DUNES

Since the sand dunes are constantly moving and changing, it is hard for life to live there. Plants get put their roots in the ground when the sand moves. Animals, though, do call the dunes home. Snakes, like the one pictured left, do very well in the sand dunes. Insects, scorpions, and even big animals like camels and elephants all call the desert home!

How Wind or Water Shapes Animal Habitats

Draw a picture here

Student Name

Table of Contents

Landform Location

Drawn map here

Written explanation here

About The Landform

Written Facts about the landform here

Picture here

Formation Focus

Picture

Information about the formation

Second Picture

How It's Formed

Drawn Model Here

Written explanation of model here

Picture

Animal Homes

Written facts about chosen animals

Picture of Animal #1

Picture of Animal #2

Constructed Explanation required for this page

Prompt: How does this formation provide a home and resources to these animals?

Book Summary

Final Constructed Explanation Written here

Prompt: how does wind or water play a role in the formation of these landforms, which then act as homes for a diversity of animals?

Final Project Rubric - How Wind or Water Forms Animal Habitats Book

Criteria	Excellent Job (5)	Great Job (4)	Good Job (3)	Getting There (2)	Nice Start (1)
Content (20 points)	All scientific content in the book is accurate and correct.	Most scientific content in the book is accurate and correct.	Some scientific content in the book is accurate and correct.	Some scientific content is incorrect or incomplete, information is missing.	Most scientific content is incorrect or incomplete, most information is missing.
Presentation (10 points)	Each page of the book contains all required materials and followed directions.	Most pages of the book contains all required materials and followed directions.	Some pages of the book contains all required materials and followed directions.	Few pages of the book contains all required materials and followed directions.	Most pages are missing information, directions were not followed. Incomplete project.
Design/Layout (10 points)	The book is neat and well organized, with bright colors, pictures, and labels for all diagrams.	The book is neat and well organized, most pictures are colored, limited spelling errors.	The book is mostly neat and well organized, contains some pictures and color.	The book is not organized well, pages are out of order, pictures are lacking color or definition.	The book is not organized or incomplete.
Explanations (20 Points)	All explanations of the formations are correct and accurate and use evidence from class activities.	All explanations of the formations are correct and accurate and use limited evidence from class activities.	One of the two explanations of the formations are correct and accurate and use evidence from class activities.	One of the two explanations of the formations are correct and accurate but is missing evidence.	Both explanations are incorrect and are missing evidence.
Final Constructed Explanation (40 points)	The final constructed explanation is complete and accurate. It includes an explanation of how wind or water changes the landforms and creates habitats for animals. Evidence is used from various sources.	The final constructed explanation is complete and accurate. It includes an explanation of how wind or water changes the landforms and creates habitats for animals. Evidence is used from one source.	The final constructed explanation is almost accurate and accurate. It includes an explanation of how wind or water changes the landforms and creates habitats for animals. Evidence is missing or incomplete.	The final constructed explanation is incomplete and inaccurate. It lacks an explanation of how wind or water changes the landforms and creates habitats for animals. Evidence is missing.	No final constructed explanation is provided.

Tab page front

Label: Developing and Using Models

Department of Education

Developing and Using Models

Tennessee Academic Standards for Science

Teacher Guide for Grade 2

Standard
2.PS3.2 – Make observations and conduct experiments to provide evidence that friction produces heat and reduces or increases the motion of an object.

Tennessee Academic Standards for Science: Page 27

Three-dimensional Learning Performance for Lesson
Students will develop and use graphical models* in order to show that friction caused by two objects reduces or increases the motion of an object** highlighting the extent of the system in which forces are acting upon the object.***

Science and Engineering Practice for Lesson
*Developing and Using Models**
The goal of this three-dimensional learning performance is for students to develop a system model for tracking the impact of the force of friction on the motion of an object. It is important for students to use their models to show that there are multiple forces at work in a system where an object's motion is reduced when it comes into contact with another object or a smooth or rough surface.

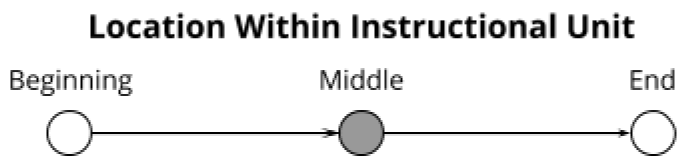
Disciplinary Core Idea for Lesson
*Physical Science 3: Energy***
An object in motion should remain in motion unless another force is present that affects motion. In the instance of a block sliding across a surface, the force of contact between the block and the surface resists the force of motion of the block. Unless the sliding block receives additional motion energy, the constant contact between the block and the surface it slides on will cause the block to slow down and eventually stop. Different factors such as the properties of materials, speed of motion, and the size of the objects will determine how much friction is present in a given circumstance.

This lesson sets students up for the bigger picture: When the motion energy of an object changes, there is inevitably some other change in energy occurring at the same time within the system. For example, the friction that causes a moving object to stop also results in an increase in the thermal energy in both surfaces; eventually, thermal energy is transferred to the surrounding environment as the surfaces cool.

A Framework for K–12 Science Education: Page 125

Crosscutting Concept for Lesson
*Systems and System Models****
Students consider the forces of friction and motion as they operate within a system involving an object in motion and a surface or other object that is resisting that motion. Students recognize that the object in motion, the surface or object that it rolls across, and the forces that exist between those objects all constitute a system. By impacting one part of the system, we can evaluate how that impacts other parts of the system as well.

Prior Knowledge



- Concepts that should be covered before this lesson:
  - Objects are put into motion when a large enough push or pull force acts upon them.
  - An object's motion does not change unless a force acts on it, such as another push or pull.
- This lesson covers portions of standard 2.PS3.2:
  - Friction is an invisible force that reduces the force of motion in an object.
  - Friction occurs within a variety of settings.
  - The amount of friction present in a system is dependent on the mass/size of the objects in motion, the speed of the objects in motion, and the materials that make up the objects and any surfaces that they contact.

Materials
- Student Activity 2.PS3.2 "How do we determine what makes a rolling ball stop?"
- Friction Record Sheet
- Two miniature car toys with wheels that spin or two tennis balls
- One ramp (made of a plank of wood about 1 meter long and 15 centimeter wide, propped up on one end by a stack of books)
- One standard bathroom towel
- One roll Scotch tape (optional: for securing the towel to the ramp or floor for the teacher demonstration)
- The following are needed for each group of two students
  - One clipboard
  - One rubber eraser
  - One glue stick (or something that can roll, such as a crayon or marker)
  - One index card
- Images of sample scenarios: Roller Skates; Snowboard Being Waxed, Snowboarder on Mountain, Athletic Gloves, Street Bicycle Tire, Mountain Bicycle Tire

Lesson Sequence and Instructional Notes

Teacher Demonstration and Student Model Development

The teacher starts with class discussion on noticing how a rolling ball always comes to a stop eventually. The teacher demonstrates this by rolling a tennis ball down the ramp, and students observe that it eventually stops rolling on the ground. The teacher provides parameters of the system involved with the demonstration: a tennis ball, a ramp, the ground. Even though air resistance could be included in the system, it is omitted, as it is beyond the scope of the science standards for this grade. One force present in the system is explained as gravity pulling the ball down the ramp. Because gravity is not an academic focus for students until fifth grade, the impact of gravity in this lesson can be referred to simply as a pull force of motion. The teacher highlights that there must be another force within the system acting on the ball or else the ball would just keep rolling forever. The teacher at this point should ask the students what makes the ball stop rolling.

It may be important to convey to students that friction causes the ball to both speed up as it travels down the ramp and slow down after leaving the ramp. In doing so, keep the focus on the energy of the system. As the ball rolls down the ramp, gravity and friction add energy to the system, after leaving the ramp, friction dissipates energy from the system. To model this, take a playground ball between your two fingers, and ask the students what they would have to do in order to make the ball roll. They should come to understand, that just hitting the ball downward (gravity) causes the ball to fall, but not necessarily roll. To make the ball roll, they must push across the top of the ball, or the bottom of the ball. A clockwise roll can be initiated by a force in the clockwise direction. On the ramp (see figure below) friction exerts this force. Once the ball has left the ramp, friction removes energy by exerting a counterclockwise force, against the rolling motion of the ball.

Students should use science notebooks to draw a diagram modeling the force of motion of the ball rolling, and then try to explain what causes the ball to stop. Students should include the ball, the ramp, and the ground after the ramp on which the ball rolls. Students should include arrows in their diagrams to show the direction of forces and can even show how relatively big or small a force is by making their arrows relatively big or small. After students create their initial diagram, the teacher repeats the demonstration but lays a towel flat on the ground at the base of the ramp. Students make predictions and then observe the outcome as the tennis ball is rolled down the ramp again and over the towel (which will most likely slow the ball down more than if there was no towel present). Students then make a second diagram in their notebooks to reflect that with a towel on the ground, the tennis ball did not roll as far as it did previously.

Teacher instruction and directions should explicitly inform students what parameters create the system in which students will explore forces of motion and friction. In the first teacher demonstration, the system involved the ramp, the tennis ball, and the floor. In the second part of the demonstration, those same elements were present, but a towel was introduced as well. In both parts of the demonstration, the forces in the system can be described as the force of motion (which is explained here as simply a pull force toward the ground) and the force of friction.

Students Investigate

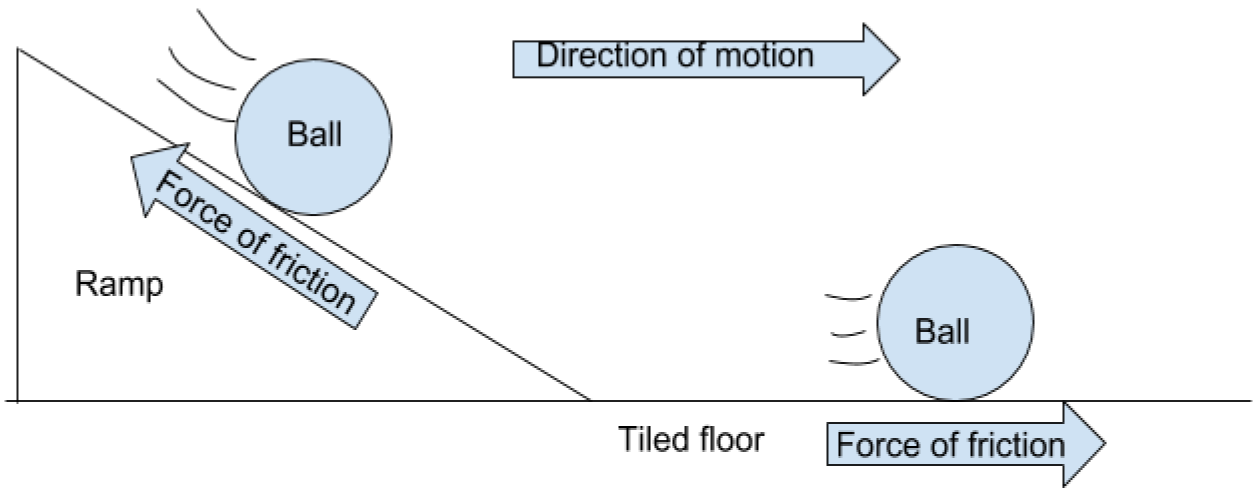
Keeping a focus on identifying parameters of a system, students will explore motion and friction with clipboards and typical desk items from their pencil box. These items could include a rubber eraser, a glue stick or marker, and an index card or a half-sheet of paper. The teacher explains that students don't have towels for this demonstration; instead, each object on their clipboard is made out of a different material, so they will be testing each object to see how well it slides off their clipboard once they begin to angle it. Keep in mind, the complexity of rolling, and focus attention on making the system slide, not roll. The teacher explains what each object is made from, and students can record the information in their notebooks. Before students begin tilting their clipboards, the teacher also establishes with students what the parameters of their system are. Students should recognize that their system will include the objects from their desk, the clipboard (serving as a ramp), and the ground (when the objects fall off the clipboard and come to a rest). Students should also recognize that the force of motion (the pull force from gravity) and the force of friction affect whether the objects move and how far they move. When students are ready, they will place the clipboard flat on the floor, or their desk, and place all three objects on the clipboard. For the purpose of this experiment, students should ensure that the items are placed at the same "starting line" on their clipboard. In fact, it may be helpful for students to lightly mark a "starting line" on the clipboard with their pencil or by taping a small line of paper across their clipboard. Then, the student will slowly begin to lift one end of the clipboard up off the floor/desk, effectively forming an inclined plane. As the student steadily lifts the clipboard to a steeper angle, they take note of which object is the first to slide off the clipboard and onto the floor/desk. Students may repeat this procedure a few times to ensure they receive consistent results. Students will model their results by drawing a diagram in their science notebook to show the system they investigated and labeling the parts of that system (clipboard, objects, floor or desk), as well as drawing arrows and labeling them to indicate the forces present in their system (force of motion and force of gravity). Students also record which item slides the easiest, which item is in the middle, and which item requires the most force to slide.

Criteria for Student Models

- Require students to draw and label arrows to represent the direction of motion and friction within their system model in their notebooks.
- Require students to match the size of their arrows to the relative strength of the force it represents (e.g., small arrow = weak force; big arrow = strong force).

- When students record their clipboard results, they should describe their items in terms of friction with the clipboard (e.g., the rubber eraser has the most friction, because it was the hardest to move).

Discussions should lead students to the creation of a model that records the types of energy and objects in the system.



Notes on using the model

- Ensure students recognize that their model represents a system with limited parameters. For example, the ceiling does not have any bearing on how far an object slides off a student's clipboard.
- Ensure students do not neglect to draw arrows and label them to represent the forces present in the system. These forces are invisible and likely some students will forget to include them as a result.

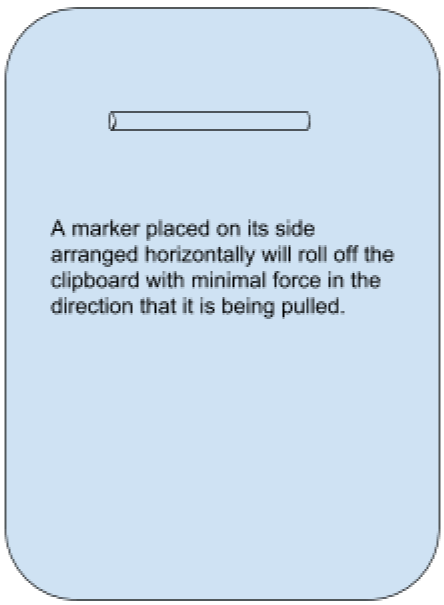
Elaboration

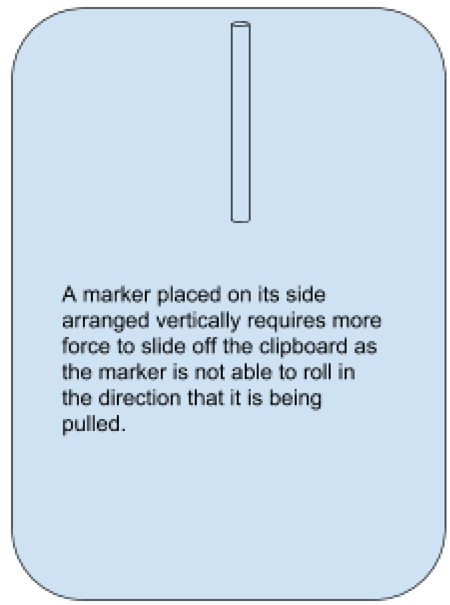
The teacher discusses the experiment results with students. Conversations might steer toward any divergent results, such as if one student had a different outcome regarding which object appeared to have the most friction acting on it. If all students achieved the same result, then the conversation could steer toward students explaining the factors responsible for the relative amounts of friction acting on the objects. Due to the presence of invisible forces within the system of study, it is recommended that for this lesson the teacher employs a whole-class discussion to moderate ideas, clarify misconceptions, and assist in establishing a baseline understanding of how friction impacts the motion of an object.

Strategy: Whole-Class Discussion

The teacher poses a question for students to answer with data and reasoning, encouraging students to talk with each other. By listening to each others' responses, a student may hear something that challenges his or her own understanding of the investigation, which can then lead to that student asking a follow-up question to the class which refines their own understanding. The teacher guides the conversation by asking follow-up questions to the class as needed and/or calling on students to share their conclusions of what they think is causing some objects to move easier than others.

Sample Question:
Why does a marker or glue stick roll easily off the clipboard if I place it on its side arranged horizontally, but it takes more force to move if I place it on its side arranged vertically?





Sample Scenarios for Student Groups to Model
Students should take one of the scenarios below and sketch a quick diagram showing one of two things: 1) A person trying to reduce the friction in a system as much as possible, or 2) A person trying to increase the friction in a system as much as possible. The student should identify the parameters of the system and should include arrows to represent the relative forces of motion and friction.

- A roller skater needs to slow down their motion. To do so, she shifts her foot to allow the rubber tip of the roller skate to come into contact with the ground.
- A snowboarder wants to travel faster down a snowy mountain and prepares by rubbing a waxy liquid on the bottom of his snowboard.

- A football player wears special gloves with tiny bumps appearing all over the section of the glove that covers the palm and the parts of fingers that would grab hold of an object.
- A mountain bike has thick tires with lots of bumps and ridges molded into the rubber material, whereas a speed bike for racing on flat surfaces has rubber tires that are very thin and smooth.

Formative Assessment
(Use Daily Lesson Formative Assessment Sheet for this Lesson: *How do we determine what makes a rolling ball stop?*)

Teacher Evaluation Notes

Item 1:
In the initial comparison between two models, it is important for students to understand a qualitative difference in observing how far the ball rolls across the floor before it comes to a stop. Students should draw the ball farther away from the ramp in the top model (with no towel) than in the bottom model (with the towel). Students demonstrate that they recognize the objects present in the system by labeling them in the models.

Note: It may be beneficial to advise students that in the bottom model, the thin rectangle placed at the bottom of the ramp is supposed to be there, and they should label it accordingly (e.g., towel).

Item 1a:
Student responses should indicate that they recognize the change to the system was the addition of a towel placed on the floor by the ramp. Students may also include that a change in the system is the ball moving more slowly when it had to move over the towel.

Item 1b:
Student responses will vary. The goal is for students to understand that the ball slows down or does not roll as far because rolling over the towel causes more friction than the tiled floor. This is because the towel is textured with lots of tiny little bumps, and the tiled floor is much smoother.

Items 2 and 3:
The model present is a depiction of a system, and students identify the components of the system by using the included word bank to label each object. Students should also draw one arrow in the direction of the ball's movement and label that arrow "force of motion," and an opposing arrow facing the reverse direction to represent the resistance of motion caused by the force of friction. Arrows should be correctly labeled "motion" or "friction." Afterward, the student explains in sentences what is occurring in the model and how the forces interact with the rolling ball.

Item 4:
Claim A is incorrect and states the inverse of the actual principle. Students choosing this claim may have equated "friction" with "how slippery an object is." A follow-up conversation would be helpful to clarify that friction is the *resistance* to motion, and the more friction in the system the less "slippery" the system would be.
Claim B is true.

Claim C is to determine if students misidentify the ball as being the only object of consequence in the system. Students should recognize that by altering the surface that the ball contacts as it rolls, the forces of motion and friction present in the system may be affected.

Citations and Resources

“Rolling Soccer Ball” Image retrieved from https://pixabay.com/en/football-ball-clip-sport-1275123/

“Roller Skates” image retrieved from https://pixabay.com/p-415389/?no_redirect

“Snowboard Being Waxed” image retrieved from https://media.defense.gov/2008/Nov/02/2000666684/-1/-1/0/081101-F-5951M-023.JPG

“Snowboarder on Mountain” image retrieved from https://upload.wikimedia.org/wikipedia/commons/f/f6/Snowboarding_in_Hippach%2C_Austria.jpg

“Athletic gloves” image retrieved from https://pixabay.com/en/door-husband-football-goalkeeper-1271621/

“Street Bicycle Tire” image retrieved from https://upload.wikimedia.org/wikipedia/commons/6/6b/Eddy_Merckx_UMX-S_Single_Speed_Bike_%289086953269%29.jpg

“Mountain Bicycle Tire” image retrieved from https://en.wikipedia.org/wiki/Mountain_bike#/media/File:Norco_Range.jpg

Name____________________________

How do we determine what makes a rolling ball stop?

All around us, every day, we see objects move and then eventually stop moving. A car moves, and then it puts on the brakes and stops. A ball rolls down a hill, but it eventually comes to a stop. Fidget spinners spin for a long time, but they eventually stop spinning. How can we explain the motion of these objects coming to a stop? What is causing them to stop?

1. In the two models below, draw a tennis ball to show how far the tennis ball travelled before it stopped moving. Also, label the following parts of the system in your model: **ramp, floor, towel, ball**.

   a. In the above picture, how did the system change from the top model to the bottom model?

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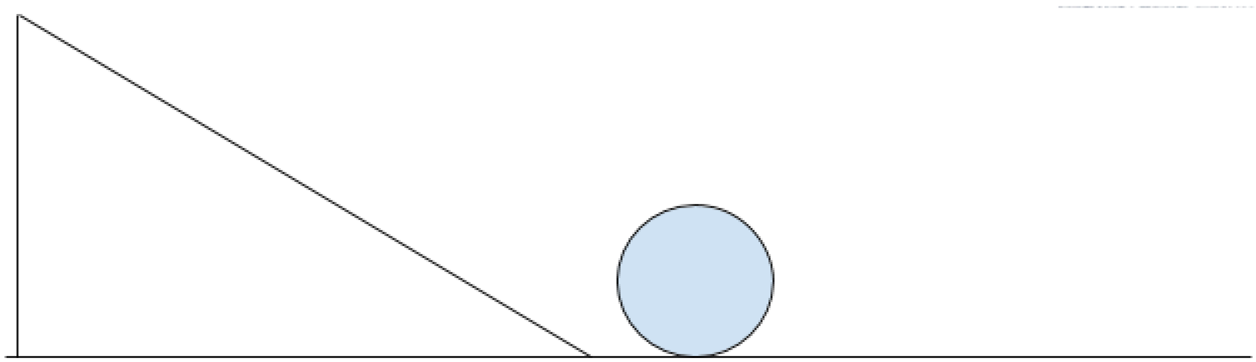
b. Why do you think adding the towel might affect the motion of the ball?

2. In the model below, the ball is rolling across the tile floor. Label the parts of the system (word bank: **ball, ramp, tile floor)**. Also, draw **two arrows** within the model to show the force of motion and the force of friction. The direction of the arrows should match the direction of the force.

   *Bonus Challenge: Label the forces correctly by matching them to the arrow that shows the direction of the force (word bank: **motion, friction**).



3. Write a description of what is happening in the model above as if you are explaining this model to your friend on the playground. (Hint: Be sure to include **arrows** to show motion and friction when you explain why the ball is rolling and why it stops!)

Image retrieved from https://pixabay.com/en/football-ball-clip-sport-1275123/

4. Let’s imagine that we take our model from Question 3 and put it on a huge sheet of very slick, slippery ice. What do you think will happen to the motion of the ball when it rolls down the ramp and rolls over the sheet of ice?

    a. The ball will roll a shorter distance because ice has more friction than carpet.
    b. The ball will roll a greater distance because ice has less friction than carpet.
    c. The ball will roll the same distance because it doesn’t matter what type of surface it rolls on.

What evidence caused you to select your answer to Question 4?

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5. **Bonus Question*: When a ball rolls down a ramp, is the ball moving because it is **pushed** by an invisible force from behind, or is it moving because it is being **pulled** by an invisible force from the ground? Explain any evidence from our demonstrations today that backs up your claim.

Image retrieved from https://pixabay.com/en/football-ball-clip-sport-1275123/

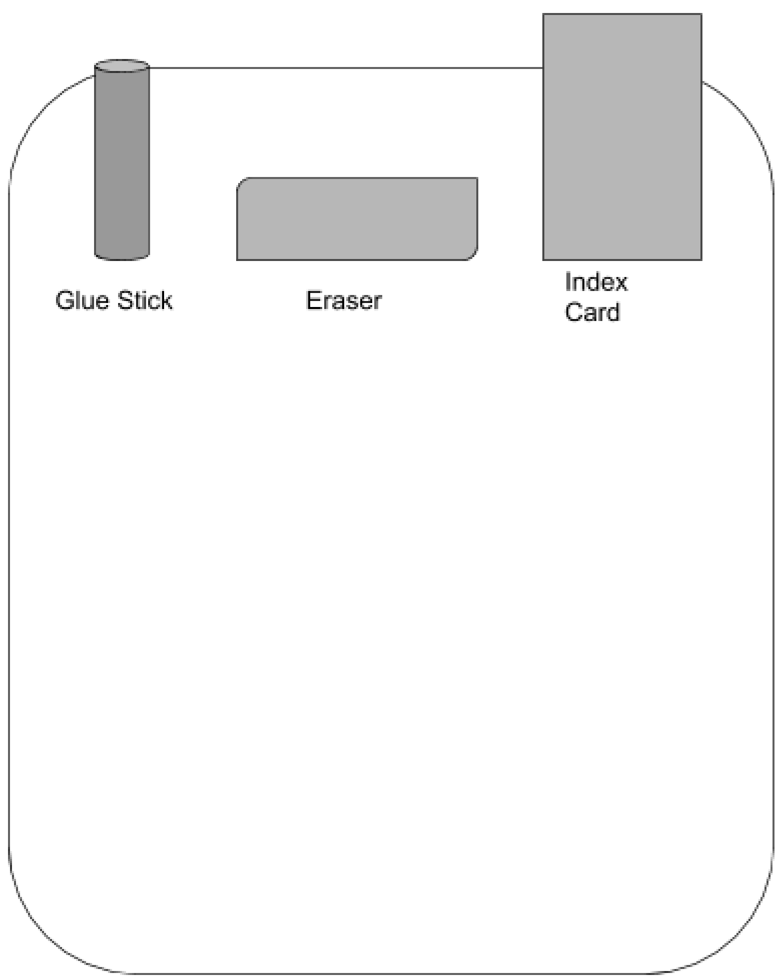
Name____________________

Friction experiment

1. Record the three items that you have placed on your clipboard. As best you can, describe the material that makes up each object.

2. What makes up the system in our experiment? Name all of the components that make up the system in our experiment.

3. Here is a diagram of the objects on your clipboard. The objects would be moving DOWN off the bottom of the clipboard for this experiment. Near each object, draw an arrow pointing UP to indicate the force of friction acting on each object. A bigger arrow indicates more friction than a smaller arrow!



Tab page front

Label: Asking Questions and Defining Problems

Asking Questions and Defining Problems

Tennessee Academic Standards for Science

Teacher Guide for Grade 2

Standard
2.ETS1.1 Define a simple problem that can be solved through the development of a new or improved object or tool by asking questions, making observations, and gathering accurate information about a situation people want to change.

Tennessee Academic Standards for Science: Page 28

Three-dimensional Learning Performance for Lesson
Students will define a simple problem that many of them can relate to[*] in order to show that a problem must first be clearly understood before it can be effectively resolved or improved[**] highlighting the relevant parts of a system that are impacted by a problem and any subsequent solutions or improvements.[***]

Science and Engineering Practice for Lesson
Defining a simple problem[*]
The goal of this three-dimensional learning performance is for students to develop a sense of how to identify and define a problem and ask relevant questions that could lead to a solution or improvement to the problem.

Disciplinary Core Idea for Lesson
Engineering, Technology, and Applications of Science 1: Engineering Design [**]
"A situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions. Asking questions, making observations, and gathering information are helpful in thinking about problems. Before beginning to design a solution, it is important to clearly understand the problem."

A Framework for K–12 Science Education: Page 205

Crosscutting Concept for Lesson
Systems and System Models[***]
"The engineering design process begins with the identification of a problem to solve and the specification of clear goals, or criteria, that the final product or system must meet."

A Framework for K–12 Science Education: Page 204

Prior Knowledge
This lesson would only come after students have already begun exploring standard 2.PS3.2. Students need to have a basic understanding that the force of friction resists the force of motion. Furthermore, students should have an understanding that friction can be increased or decreased—which will impact the motion of an object.

- Concepts that should be covered before this lesson:
  - A friction force is present when an object or surface comes into contact with another object or surface.
  - Friction resists the force of motion

- This lesson covers portions of standard 2.ETS1.1:
  - By observing a circumstance, situation, or object, we can identify ways that it might be more conducive to human goals (e.g., an airplane's wings are redesigned to reduce air resistance and improve fuel efficiency, reducing overall cost of travel).

Materials
- Science notebooks or sheet for recording thoughts
- One sheet of wax paper
- One sheet of sandpaper
- Denim fabric (rougher denim preferred over faded, smoother denim)
- A fabric smoother than denim, such as khaki or athletic-wear (optional)
- Images of playground slides (found with an image search on an internet search engine)
- Actual playground slide*

**Note: If a playground slide is not available at your site, this investigation can still be performed in a similar manner by setting up "mini-slides" in the classroom using inclined planes. These inclined planes can be quickly established by arranging any flat surface at an angle relative to the ground. For example, a plank of wood can be set up to lean against a student desk so that a ball could be rolled down the plank and across the floor. Different materials can be draped over the inclined plane one at a time and students can observe how that material impacts the speed of the ball. A long ramp will provide a longer period of observation and may allow for greater differences in observable data. Multiple "mini-slides" could be set up in the classroom this way.*

Lesson Sequence and Instructional Notes

Teacher-led Discussion and Student Development of Defining the Problem

The teacher begins by calling on students to elicit prior knowledge from earlier lessons about the force of friction. Once the class recalls that friction is a force present in a system that resists the force of motion within that same system, the teacher asks for some real-life examples of systems that involve friction and writes those on the board. For example, a roller skater slows down their motion more quickly by maintaining contact between the rubber brake on their skate and the ground. Once several situations are generated, the teacher will then show an image of a playground slide. The teacher challenges students to think about a time when they went down a slide: “Is it the same experience going down every slide?” “What makes certain slides ‘better’ than other slides?” “What would a perfect slide be like?” Have students turn to a shoulder-partner and quickly share one thought about what would make for a perfect slide.

The teacher then asks students to share out the features that a perfect slide would have. If students don’t mention anything about going down the slide fast, the teacher should prompt students to consider whether a perfect slide would have them sliding down it fast or slowly. Once students agree that they would go down a perfect slide fast, the teacher redirects students to start thinking about their own playground slide or a local slide at a park. The teacher prompts students to think about what some of the ways they would want to improve their experience going down that slide. While they think, the teacher hands out a copy of 2.ETS1.1 Student Activity Sheet to each student and instructs them to complete the first page only. The teacher reads the introduction sentences on the sheet and then provides a couple minutes for students to brainstorm ideas about the perfect slide using the first part of the sheet.

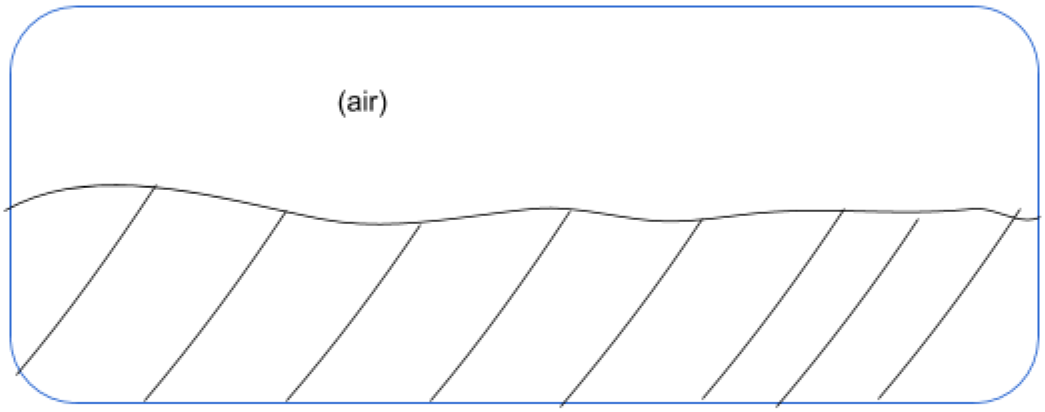
After this time, the teacher calls on a few different students to each share one of their ideas. Students may have a variety of answers such as “building a really tall ladder,” “making it super slippery,” “making it into a slip n’ slide,” etc.

After hearing a number of ideas, the teacher instructs students to turn to Page 2 and reads aloud the disappointing news: there are rules! Read each of the three rules to the students so they understand that they will need to think about and redefine the problem with these new constraints in mind. To help students with their thinking, have them do Question 2 on the *Student Activity Sheet* where they identify the parts of the system that they could potentially alter with these new rules in place.

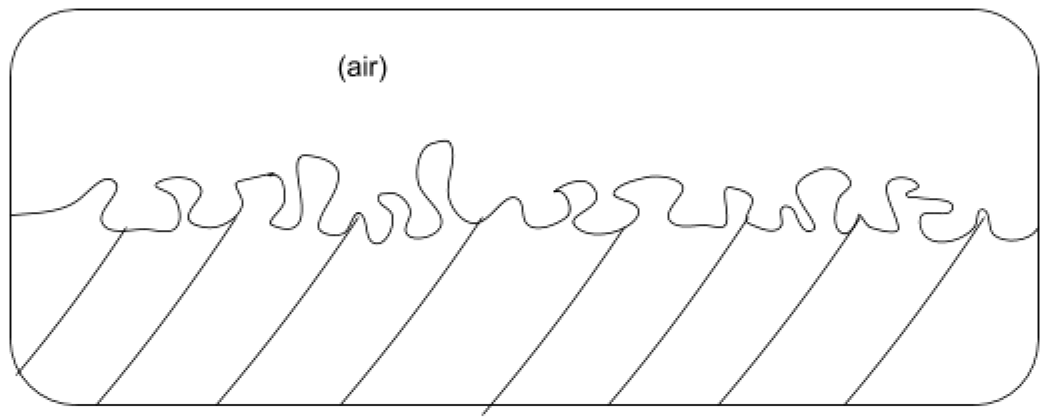
Before having students move on to Questions 3 and 4 on the *Student Activity Sheet*, first proceed with the teacher demonstration.

Teacher Demonstration

The teacher calls students to gather near a demonstration table where there is a piece of sandpaper and a piece of wax paper. The teacher explains to students that this demonstration is to quickly review what happens when different materials slide over the same surface, to see if we can gather any insight into how this could help us with our slide problem. The teacher takes both pieces of paper and slides each of them along the demonstration table. The wax paper should slide very easily while the sandpaper hardly slides at all. The teacher draws two diagrams on the board to model for students what the surface of the paper might look like if we were able to zoom in on it very, very closely. A representation of the diagrams is included for the teacher on the following page. Students should begin to recognize that friction is increased as the surface gets rougher. The teacher then shows the class an item made out of denim and students discuss whether denim is more similar to wax paper or sandpaper. Then, ask students if anyone can think of what kind of pants might be made from fabric that is smoother than denim. Possible answers might include athletic shorts, track pants, khakis, dress-up pants, etc. An optional material such as khaki can be presented to students so that they can feel the difference between fabrics.



The surface of wax paper would appear smooth and wavy if we were to zoom in a whole lot.



The surface of sandpaper would appear very rough and jagged if we were to zoom in a whole lot.

After having this discussion about pant fabric material, the teacher instructs students to complete Question 3 on their *Student Activity Sheet*.

Though this lesson concludes with a formative assessment series of questions for students to respond to, consider providing opportunities for students to bring in different kinds of fabrics or clothes in subsequent days so that they can authentically experience how this impacts their experience of sliding down the slide.

Formative Assessment

(Use daily lesson formative assessment sheet for this lesson)

As a final assessment question for the lesson, have students complete Question 4 on the *Student Activity Sheet*. This question may require students to reread the paragraph, so it may take some of them longer to finish than others. If this is the case, students who finish first may draw a model on the back of their paper of the football player catching the ball or running down the field fast. Remind students who do this that their model should include labels for people or objects and arrows to represent the relevant invisible forces acting within the model.

Teacher Evaluation Notes

Items 1a and 1b:
Student responses to Item 1a should indicate that the force of friction will need to be reduced for someone to go faster down a slide. For 1b, student responses will vary, but any answer that relates to enabling us to slide faster should be accepted as long as the student also provides a reason to justify their idea.

Item 2:
Students should mark an "X" through each part of the model except the person wearing jeans who is on the slide, which they should have circled. This is to help students recognize that to improve the experience of sliding down the playground slide, they need to define the problem in terms of what material their pants are made from since that is the only part of the system they are able to affect.

Item 3:
Student responses should demonstrate that they understand that they can improve the speed of the person in the model if that person were to change the material of their pants from denim to a smoother material that would cause less friction with the material of the slide.

Items 4a, 4b, 4c:
4a responses should indicate the student understands that the football gloves help the player catch the ball (which is part of the goal of the football player).

4b responses should reflect that the student understands the football player's goal after catching the ball is to run as fast as they can down the field to score a goal for their team.

4c responses could include any reasonable tool or device that would help a football player run down the field faster. Practically speaking, this response will most likely include some type of new or improved footwear (e.g., football cleats); however, any reasonable response, however impractical, is accepted as long as the student demonstrates an understanding that their idea would help the football player better achieve their goal of running down the field to score points.

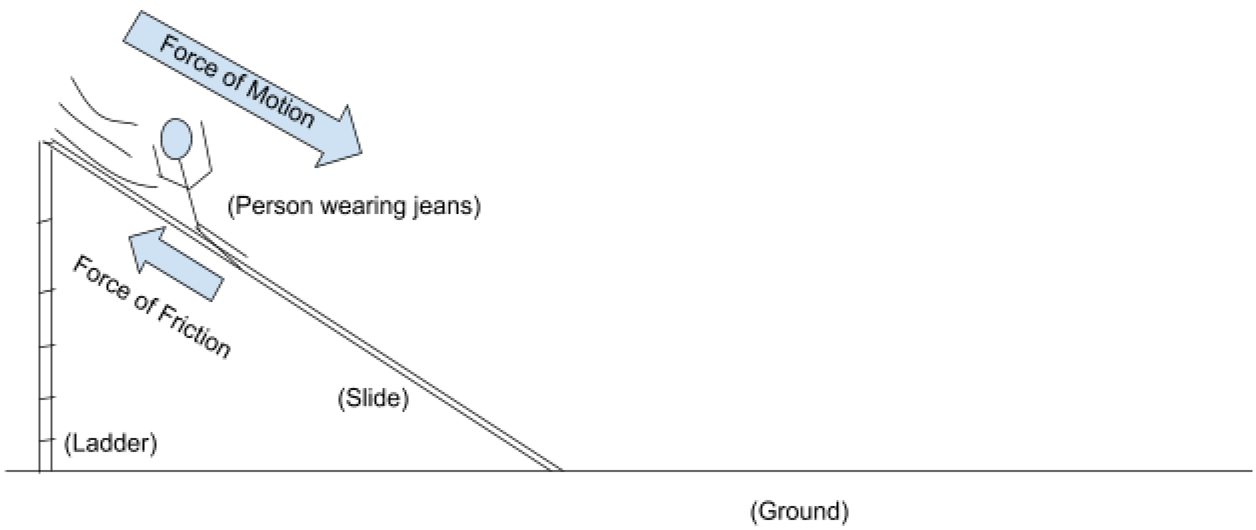
Citations and Resources
Original idea for lesson retrieved from www.mysteryscience.com

Name______________________________

All problems a-"slide"

Slides can be really fun, or they can be boring. Let's think for a moment about the slide on our playground or a slide in a local park. How could we have more fun while sliding down the slide?

1. Let's first think about what is involved in a person going down a slide. The model below can help remind us of the visible elements as well as the invisible forces within the system.



a. In the picture above, which force are we trying to *reduce*, or make smaller, so that we can go down the slide faster?

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b. What is one change we could make in the model above so that we could slide faster? How do you know that change would help us slide faster?

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"Canadian National Exhibition Big Slide" Retrieved from https://commons.wikimedia.org/wiki/File:Canadian_National_Exhibition_Big_Slide.JPG

Name______________________________

After speaking with the principal and other adults at the school, it has been determined that there are three rules we must follow when thinking about the slide.

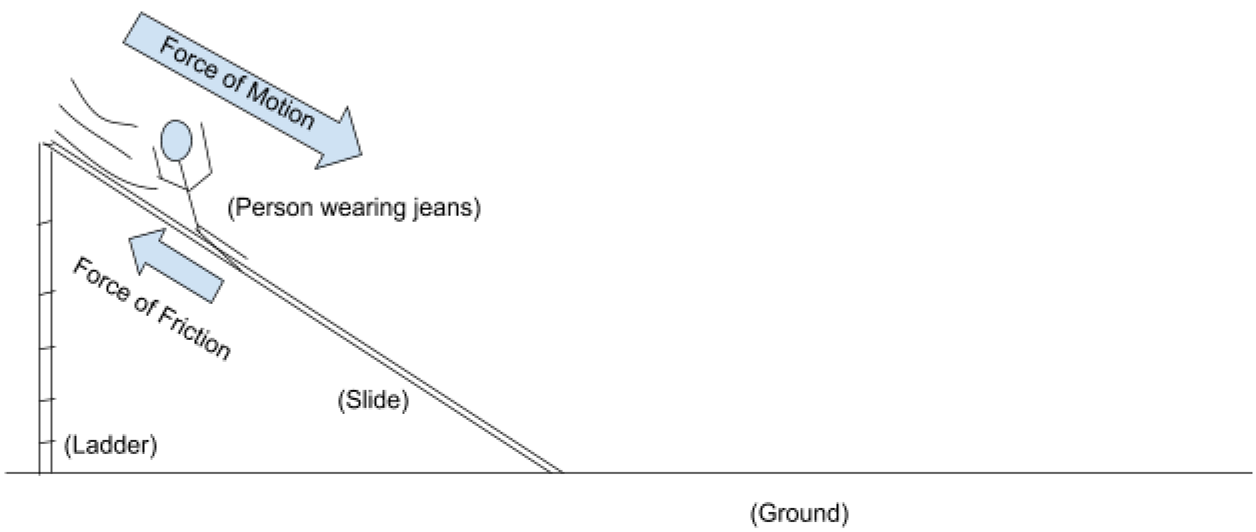
Rule #1: The slide and ladder would be too difficult and costly to change, so the slide and ladder will have to stay the same.

Rule #2: The ground has to stay the same for safety reasons; otherwise, people might slip and fall when they are running around on the playground.

Rule #3: The slide cannot have grease, oil, or water put on it to make it more slippery.

We aren't going to let these rules stop us from thinking of a solution though! We will think about this problem as engineers! We will start by figuring out what we can and cannot change in this system.

1. This is the same picture that was in Question 1. Locate all of the terms in parentheses (*Ladder, Slide, Person wearing jeans, Ground*). This time, put an "**X"** and cross out each of those things that we cannot change. **Circle** anything that we still might be able to change.



2. For each item that you circled, what is one idea that you have for how we could change that item so we could go faster down the slide?

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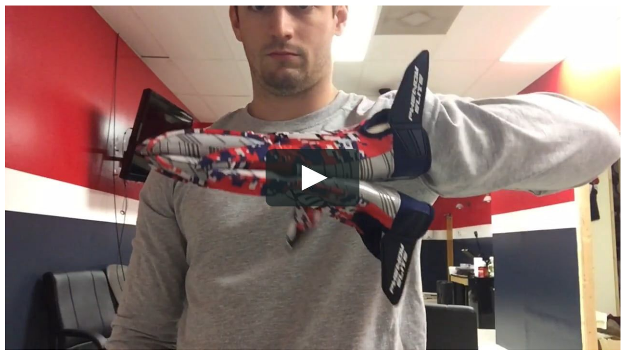
Name_______________________________

End-of-lesson assessment questions

3. Professional athletes look for every advantage they can find when they are competing in a sport. You can often see an athlete wearing special clothes or equipment to help them either reduce or increase friction in their sport as they compete. In the picture below, you can see a football player trying out some new gloves. The gloves are made from certain materials that can stick to things very well. This player's job is to catch the football if it is passed into the air. After catching the ball, this player should run as fast as they can down the field to try and score points for their team.



a. What characteristic or property of these gloves would be the most important to a football player like this one?

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b. What is something that the football player needs to do to score points after he catches the ball that would NOT be affected by gloves? (Hint: Reread the paragraph above if you are unsure!)

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c. Special gloves like the ones pictured above are tools that will give the football player a better chance at scoring points for their team. What is another tool that will help the football player score points AFTER they have already caught the ball?

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Image of football gloves sticking retrieved from https://vimeo.com/151674965