TN Department of Education

Teacher Training Grade 5

Tennessee Academic Standards for Science

Tennessee Department of Education | Summer 2018

TN Department of Education

Welcome, science teachers!

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

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

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

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

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Digital Training Resources

Access Teacher Training Digital Resources here:

goo.gl/hss2EY **or**

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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

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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

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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

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A Framework for K–12 Science Education

Key Terms from the Framework

Term	Notes
Discipline	
Dimension	
Three-dimensional	
Phenomena	
Grade Band Endpoints	

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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:

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Three-dimensional Science Instruction

Science and Engineering Practices (SEPs)

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

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

Three Science Words We Should Stop Using

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

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

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

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

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

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

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

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

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:

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Three-dimensional Science Instruction

Science and Engineering Practices (SEPs)

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

Using Mathematics and Computational Thinking

Analyzing and Interpreting Data

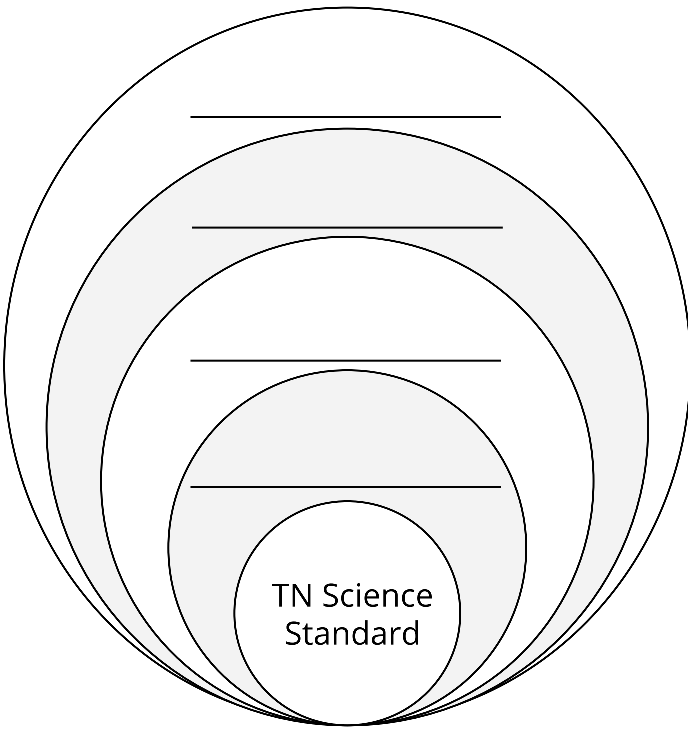
Engaging in Argument from Evidence

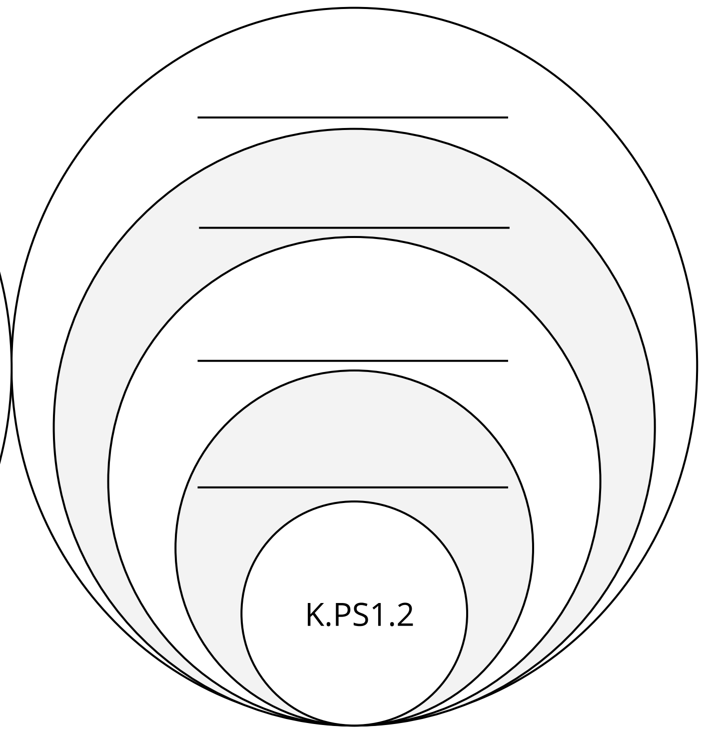
Obtaining, Evaluating, and Communicating Information

Three-dimensional Science Instruction

Disciplinary Core Ideas

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





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

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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.**

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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

Fifth Grade Standards

5.PS1: Matter and Its Interactions

1) Analyze and interpret data from observations and measurements of the physical properties of matter to explain phase changes between a solid, liquid, or gas.

2) Analyze and interpret data to show that the amount of matter is conserved even when it changes form, including transitions where matter seems to vanish.

3) Design a process to measure how different variables (temperature, particle size, stirring) affect the rate of dissolving solids into liquids.

4) Evaluate the results of an experiment to determine whether the mixing of two or more substances result in a change of properties**.**

5.PS2: Motion and Stability: Forces and Interactions

1) Test the effects of balanced and unbalanced forces on the speed and direction of motion of objects.

2) Make observations and measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.

3) Use evidence to support that the gravitational force exerted by Earth on objects is directed toward the Earth's center.

4) Explain the cause and effect relationship of two factors (mass and distance) that affect gravity.

5) Explain how forces can create patterns within a system (moving in one direction, shifting back and forth, or moving in cycles), and describe conditions that affect how fast or slowly these patterns occur.

Fifth Grade Standards

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

1) Compare and contrast animal responses that are instinctual versus those that that are gathered through the senses, processed, and stored as memories to guide their actions.

5.LS3: Heredity: Inheritance and Variation of Traits

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.

2) Provide evidence and analyze data that plants and animals have traits inherited from parents and that variations of these traits exist in a group of similar organisms.

5.LS4: Biological Change: Unity and Diversity

1) Analyze and interpret data from fossils to describe types of organisms and their environments that existed long ago. Compare similarities and differences of those to living organisms and their environments. Recognize that most kinds of animals (and plants) that once lived on Earth are now extinct.

2) Use evidence to construct an explanation for how variations in characteristics among individuals within the same species may provide advantages to these individuals in their survival and reproduction.

5.ESS1: Earth's Place in the Universe

1) Explain that differences in the apparent brightness of the sun compared to other stars is due to their relative distances from the Earth.

2) Research and explain the position of the Earth and the solar system within the Milky Way galaxy, and compare the size and shape of the Milky Way to other galaxies in the universe.

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Fifth Grade Standards

5.ESS1: Earth's Place in the Universe—Continued

3) Use data to categorize different bodies in our solar system including moons, asteroids, comets, and meteoroids according to their physical properties and motion.

4) Explain the cause and effect relationship between the positions of the sun, earth, and moon and resulting eclipses, position of constellations, and appearance of the moon.

5) Relate the tilt of the Earth's axis, as it revolves around the sun, to the varying intensities of sunlight at different latitudes. Evaluate how this causes changes in day-lengths and seasons.

6) Use tools to describe how stars and constellations appear to move from the Earth's perspective throughout the seasons.

7) Use evidence from the presence and location of fossils to determine the order in which rock strata were formed.

5.ETS1: Engineering Design

1) Research, test, re-test, and communicate a design to solve a problem.

2) Plan and carry out tests on one or more elements of a prototype in which variables are controlled and failure points are considered to identify which elements need to be improved. Apply the results of tests to redesign the prototype.

3) Describe how failure provides valuable information toward finding a solution.

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

1) Use appropriate measuring tools, simple hand tools, and fasteners to construct a prototype of a new or improved technology.

Fifth Grade Standards

5.ETS2: Links Among Engineering, Technology, Science, and Society—Continued

2) Describe how human beings have made tools and machines (X-ray cameras, microscopes, satellites, computers) to observe and do things that they could not otherwise sense or do at all, or as quickly or efficiently.

3) Identify how scientific discoveries lead to new and improved technologies.

Tab page

Label: Day 2

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Teacher Training Day Two

Tennessee Academic Standards for Science

Why new standards?

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

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

<table>
<tr><th colspan="2">Instruction</th></tr>
<tr><td>Thinking</td><td>The teacher thoroughly teaches two or more types of thinking:
● analytical thinking, where students analyze, compare and contrast, and evaluate and explain information;
● practical thinking, where students use, apply, and implement what they learn in real-life scenarios;
● creative thinking, where students create, design, imagine, and suppose; and
● research-based thinking, where students explore and review a variety of ideas, models, and solutions to problems.

The teacher provides opportunities where students:
● generate a variety of ideas and alternatives;
● analyze problems from multiple perspectives and viewpoints; and
● monitor their thinking to insure that they understand what they are learning, are attending to critical information, and are aware of the learning strategies that they are using and why.</td></tr>
<tr><td>Problem Solving</td><td>The teacher implements activities that teach and reinforce three or more of the following problem-solving types:
● Abstraction
● Categorization
● Drawing Conclusions/Justifying Solutions
● Predicting Outcomes
● Observing and Experimenting
● Improving Solutions
● Identifying Relevant/Irrelevant Information
● Generating Ideas
● Creating and Designing</td></tr>
</table>

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?

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<table>
<tr><th colspan="2">Instruction</th></tr>
<tr><td>Motivating Students</td><td>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.</td></tr>
<tr><td>Activities and Materials</td><td>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.</td></tr>
</table>

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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.

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.

Literacy in the Science Classroom

Speaking	Reading
Writing	Viewing
Showing	Listening

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Instructional Strategies

Spend a Buck

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

Notes:

Three-Dimensional Instruction

Using a new type of teaching in the science classroom

by Joe Krajcik

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

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

What is different with three-dimensional learning?

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

How often should each dimension be used?

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

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

Scientists and engineers work in three dimensions

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

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

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

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

Where to start?

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

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

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

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

Conclusion

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

FIGURE 1 Characteristics of phenomena and questions

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

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

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

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

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

Sustainable
- Learners can pursue exploration of the phenomenon over time.

Acknowledgments

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

References

Duncan, G.R., and V. Cavera. 2015. DCIs, SEPs, and CCs, oh my! Understanding the three dimensions of the *NGSS*. *Science and Children* 52 (2): 16–20; *Science Scope* 39 (2): 50–54; *The Science Teacher* 82 (7): 67–71.

Krajcik, J.S., and C. Czerniak. 2013. *Teaching science in elementary and middle school classrooms: A project-based approach.* 4th ed. London: Routledge.

National Research Council (NRC). 2012a. *Education for life and work: Developing transferable knowledge and skills in the 21st century.* Washington, DC: National Academies Press.

National Research Council (NRC). 2012b. *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: National Academies Press.

National Research Council (NRC). 2007. *Taking science to school: Learning and teaching science in grades K–8.* Washington, DC: National Academies Press.

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

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

Resources

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

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

TN Department of Education

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*

Sample Three-dimensional Planning Tool

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

A. Identify a Science and Engineering Practice

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

Consider all that apply and select one for this lesson:

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

B. Break Down the Science and Engineering Practice

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

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

Engaging in Argument from Evidence #2:

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

Sample Three-dimensional Planning Tool

Step 5: Identify and Break Down a Crosscutting Concept

A. Identify a Crosscutting Concept

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

Consider all that apply and select one for this lesson:

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

B. Break Down the Crosscutting Concept

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

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

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

Step 6: Write a Three-dimensional Learning Performance

Possible Template:

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

Sample:

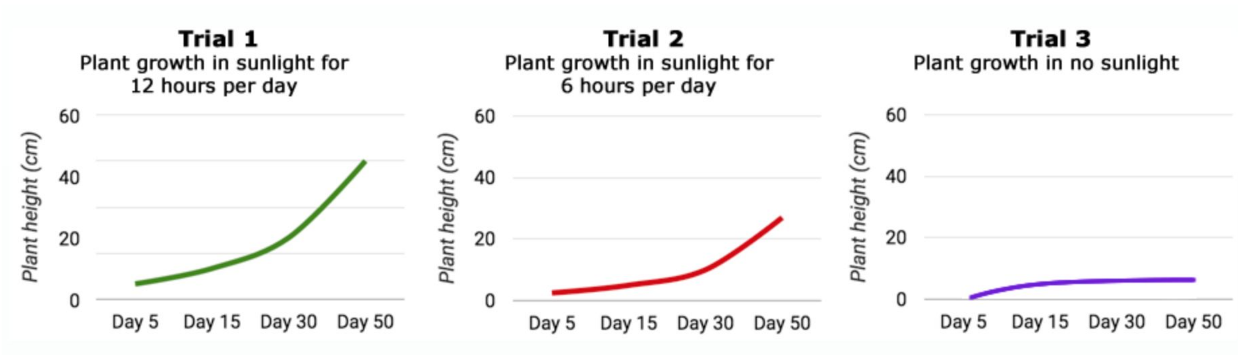
"Students will
compare and refine arguments based on an evaluation of the evidence presented
in order to show
organisms obtain gases and water from the environment and release waste matter back into the environment
highlighting that
matter is transported into, out of, and within systems."

Sample Three-dimensional Planning Tool

Step 7: Write Multidimensional Questions

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

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



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

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

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

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

Sample Three-dimensional Planning Tool

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

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

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

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

Sample Three-dimensional Planning Tool

Bullet Point Lesson

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

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

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

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

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

Sample Three-dimensional Planning Tool

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

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

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

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

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

TN Department of Education

Three-dimensional Planning Tool

Step 1: Select a Standard

Standard:

Step 2: Identify and Break Down Disciplinary Core Idea

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

Disciplinary Core Idea:

(Optional) Component Idea:

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

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

C. Identify Instructional Focus

What content will be the focus of this lesson?

Three-dimensional Planning Tool

Step 3: Brainstorm Instructional Scenarios and Select One to Use

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

A. Identify a Science and Engineering Practice

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

Consider all that apply and select one for this lesson:

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

TN Department of Education

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.

TN Department of Education

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: Using Mathematics and Computational Thinking

TN Department of Education

Using Mathematics and Computational Thinking

Tennessee Academic Standards for Science

Teacher Guide for Grade 5

Standard
5.PS2.2 Make observations and measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.

Tennessee Academic Standards for Science: Page 42

Three-dimensional Learning Performance for Lesson
Students will make observations and measurements of a pendulum* in order to show that graphs of an object's motion can be used as evidence to predict future motion** highlighting the patterns seen when changing specific variables of the pendulum.***

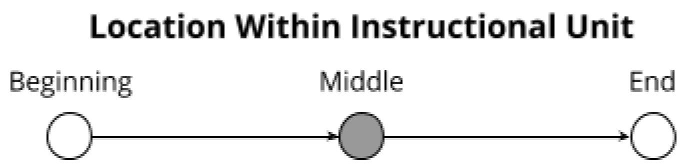
Science and Engineering Practice for Lesson
*Using Mathematics and Computational Thinking**
Students in fifth grade are ready to use mathematics as a tool in order to make and test predictions. In this lesson, students will make multiple measurements of the motion of a pendulum as it varies with changes in specific variables. Based on these measurements, students will develop a data set and use this set to reveal patterns that can be used to predict future motion.

Disciplinary Core Idea for Lesson
*Physical Science 2: Motion and Stability: Forces and Interaction***
The patterns of an object's motion in various situations can be observed and measured; when past motion exhibits a regular pattern, future motion can be predicted from it. (Boundary: Technical terms, such as magnitude, velocity, momentum, and vector quantity, are not introduced at this level, but the concept that some quantities need both size and direction to be described is developed.)

A Framework for K–12 Science Education: Page 115

Crosscutting Concept for Lesson
Patterns***
In this lesson, students will use a simple pendulum system to investigate the change in three variables and look for patterns in the resultant data sets. Students will then use the patterns as evidence to make predictions about future motion. Students will recognize, classify, and record patterns involving rates of change.

Prior Knowledge



- Concepts that should be covered before this lesson:
    - The concept of "net forces" that act on objects
    - The effects of both balanced forces, which will not change the motion of an object, and unbalanced forces, which do change the motion of an object
    - A stable system is one in which the internal and external forces are such that any small change results in forces that return the system to its prior state (e.g., a weight hanging from a string).
- This lesson covers all of standard 5.PS2.2:
    - Make observations and measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.

Materials (Listed in Order Needed for Lesson)

The following simulation can be used at any point in the lesson for additional clarification: https://phet.colorado.edu/sims/html/pendulum-lab/latest/pendulum-lab_en.html

- String
- Paper clips (two for each pair of students.)
- Masking tape
- Pennies (will need 60-80 pennies depending on class size)
- Unsharpened pencils
- Meter sticks
- Scissors
- Pre-made number line (instructions in Teacher Guide)
- Protractors
- Calculator
- Timers
- Chart paper with T-Chart

Lesson Sequence and Instructional Notes

The terminology used in the included teacher notes has been selected for sake of clarity, and invokes skills, such as plotting a line of best fit, that exceed a students mathematical understanding. The task of drawing a line of best fit can simply be expressed as drawing a single line with a rules that will pass through as many points as possible, since plotting points is grade-level appropriate. This will create variation in student responses, but provides an opportunity for students to gain exposure to higher level math skills. To introduce students to the skill of making predictions from their line of best fit, the process can be broken down into drawing of horizontal/vertical lines which intersect their line of best fit, then a second vertical/horizontal line to estimate a predicted value.

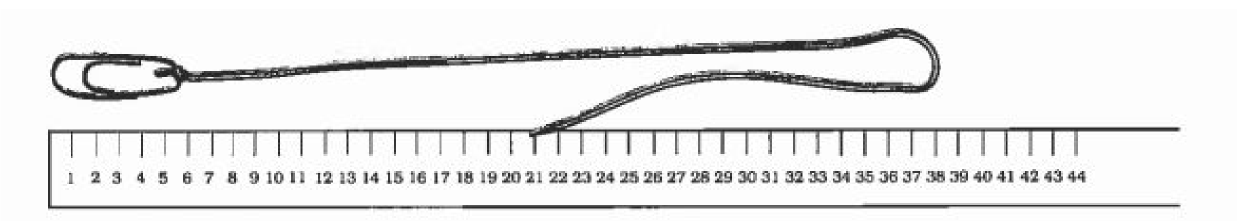
Begin by having students read the introductory text at the top of the student activity sheet. This text provides background information on how Galileo Galilei observed patterns in the swinging motions of lights and eventually used experimental data about this motion to develop a type of pendulum clock.
Tell students that they will be making and using a simple pendulum system and will do some of the same experiments that Galileo did hundreds of years ago. Tell students that the experiments they are going to do today all involve seeing what types of things will change the motion of the pendulum.

It is suggested that students work in pairs for this activity.

The instructions for making the pendulum are included on the student activity guide but are also included here for convenience. Students may need a step-by-step visual to follow as the teacher constructs one to demonstrate. Encourage students who finish early to go ahead and begin to explore the pendulum system while others finish building.

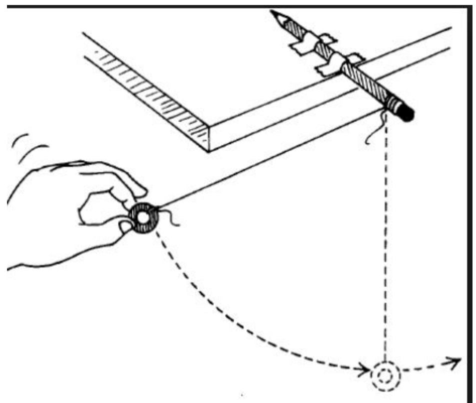
Let's build a pendulum. Here's what you will need:

string (about 50 cm)	metric meter stick
1 paper clip	1 penny
masking tape	1 pencil



A. Tie one end of the string securely to the paper clip.
B. Measure exactly 38 cm from the tip of the paper clip along the string. Fold the string back at exactly the 38 cm mark.
C. Put a tiny piece of masking tape around the string to make a loop. The loop should be large enough to hang over a pencil. Remeasure to make sure the pendulum measures 38 cm from the tip of the paper clip to the top of the loop.
D. Clip a penny in the paper clip.
E. Tape an unsharpened pencil onto a flat desk. Make sure the pencil extends about halfway out over the edge. Hang the loop of string onto the pencil. You

have made a pendulum!



After all students have made pendulums, tell them that it is time to do Experiment #1!

Experiment #1 is located on the student activity guide.

- Ask: How many times do you think your pendulum will swing in 20 seconds? How can we find out? *It is important to guide students into understanding that everyone in the class must start the pendulum from the same height. The class must also agree on what exactly equals "a swing." Students also need to decide who/how the experiment will be timed. These decisions help students to understand that science is conducted in a deliberate, methodical way that involves making sure that experiments can be replicated and that results are not biased. It is suggested that all students start with the penny held even to the top of the table. A "swing" would be defined as the penny moving away and then back to its original starting point. Teachers will probably want to be the official timer for Experiment #1.*

Have students do three trials and complete the data table on the student activity guide. The table also asks students to determine the mean for their data. Students may need to be reminded about how to determine the mean for a set of numbers.

Poll the class to compare the mean for each pair of students. This is an opportunity to have a class discussion about why some students may have slightly different answers and how hard it is to make sure that everything is the same as much as possible when doing an experiment. Students should complete the question on the activity sheet that asks how their mean compares with their classmates.

- Ask students: What could we change in our pendulum system that might change the number of swings in 20 seconds? Anything that we can change in a system that might affect the outcome is called a *variable*. When scientists conduct experiments, it is important to only test ONE variable at a time. *Students will probably suggest changing the length of the string, the force with which the penny is pushed, the height that the pendulum starts at, and the number of pennies that are attached. All of these are examples of variables. The students will NOT be doing an experiment to change the* *amount of force. The force of gravity will be the only force acting on the pendulum. However, the other three variables will all be explored in each of the experiments that the students will be completing.*

Students should now find **Experiment #2** on the student activity sheet. In this experiment, they will see how the release angle affects the number of swings in 20 seconds. Hand out protractors to the students. Students will align the protractor with the flat side up and the curved side down.

- Ask: What are we getting ready to change? *The release angle. This is the independent variable.*
- Ask: What will we measure or count? *The number of swings. This is the dependent variable.*

Have students complete the data table for 0, 20, and 40 degrees. They should then STOP and answer the following on their student activity sheet:

Based on the evidence that you have collected, how does the angle of release affect the number of swings of the pendulum? *The angle of release usually has very little effect on the number of swings. Essentially, the number of swings should remain fairly constant and be the same.*

Using the pattern in your data, predict the number of swings that will result from a release angle of 60 degrees. Explain HOW you used the data to make your prediction. *Since the first three angles all result in the same number of swings, the 60 degree angle should also result in the same number of swings.*

Teachers may want to again poll the whole class to compare answers at this point. However, the consensus should be that the number of swings stays constant. Allow students to now test the pendulum at the 60 degree angle to see if their prediction is correct. Students should note on their activity sheet how close their prediction was to the actual value.

Tell students to go to **Experiment #3** on their activity sheet. This experiment will test how mass affects the number of swings. We will change the mass by changing the number of pennies that are attached to the paper clip.

- Ask: What are we changing? *The number of pennies. This is the independent variable.*
- Ask: What will we measure or count? *The number of swings. This is the dependent variable.*

Point out to students that the only thing that will change is the number of pennies. They should follow the pre-set data table and keep the release angle exactly the same each time.

Have students complete the trials for 1, 2, and 3 pennies and then STOP and answer the questions on the activity sheet:

Based on the evidence that you have collected, how does the mass of the bob affect the number of swings of the pendulum? *The mass does not affect the number of swings. It stays the same.*

Using the pattern in your data, predict the number of swings that will result from a mass of **four** pennies. Explain HOW you used the data to make your prediction. *Since increasing the number of pennies has not changed the number of swings, using four pennies should not change the number of swings either.*

Teachers may want to engage in whole class discussion again at this point to compare answers. However, the general consensus should be that changing the mass of the bob does not change the number of swings. Students should note on the activity sheet how close their prediction was to the actual value.

Tell students to go to **Experiment #4** on their student activity sheet. This experiment will be a bit more complicated than the first two experiments that have been completed.

Before beginning Experiment #4, be sure to have prepared the number line and a piece of chart paper for students to record their data. This will allow the entire class to see the results of the experiment.

To Prepare the Number Line:
Write the numbers of swings (5-25) across the top of a white board or other available space. The students will be taping the strings of their pendulums below the number that matches the number of swings that results from the specific length they will be testing. In this way, a visual graph is created for the students to see the relationship between string length and number of swings.

Experiment #4 will test how changing the length of the string affects the number of swings.

- Ask: What are we changing? *The length of the string. This is the independent variable.*
- Ask: What are we going to measure or count? *The number of swings. This is the dependent variable.*

Tell students that they will use the 38 cm pendulum as a standard of comparison to the other lengths of string that they will be testing. This is called a *control*.

Show students the number line that you have placed on a wall of the classroom. This number line will provide a visual graph for students to use. Each number represents a different number of pendulum swings. Tell students to locate the mean number of swings that they recorded in **Experiment #1**. They should hang their pendulum on the number that is closest to their mean number of swings. *Almost all of the students should end up hanging their pendulum on the same number. You might have a few outliers, but that is fine.*

You will now assign a NEW length of string to each pair of students. Each pair of students is responsible for:

1. Testing the new length and recording the results in their data table on the activity sheet.
2. Calculating the mean for their three trials.
3. Recording their results on the chart paper so the whole class can see.
4. Hanging their pendulum on the number line to show their mean number of swings.

The following lengths should be tested. These lengths represent the length from the tip of the paper clip to the loop in the string.

13 cm	20 cm	33 cm	90 cm
15 cm	22 cm	45 cm	100 cm
17 cm	25 cm	55 cm	170 cm
18 cm	29 cm	70 cm	200 cm

Note that some of the longer lengths will require students to hang the pendulum from a higher surface such as a filing cabinet. It is not necessary to assign all of the lengths, but enough of them should be assigned so that the pattern is revealed.

Bring the whole class back together to examine the number line. Students should be able to see a relationship between the length of the string and the number of swings of the pendulum. *As the length of the string increases, the number of swings decreases. As the length of the string decreases, the number of swings increases.*

Students should record this information on their student activity sheet.

Have students record the data from the class chart paper onto the T-chart in their student activity sheet.

Length of String	Number of Swings

Tell students that scientists usually make a graph of their data so that they can use the data even more. You are going to help the students take the data from the T-chart and turn it into a graph.

Teachers should use a document camera or other method of displaying the graph to the students.

A. Point out the features of the graph to the students. *The independent variable is on the X-axis. The dependent variable is on the Y-axis. Labels and units are both included.*
B. Tell students that we need to decide on the numbers that we should add on the Y-axis. This is often a difficult skill for students. Model this process for students as you ask for the smallest number of swings and the greatest number of swings to determine the range that needs to be reflected on the graph. Add the numbers on the Y-axis.
C. Show students how to plot each point onto the graph.
D. Show students how to draw a “line of best fit” through most of the data points on the graph.
E. Explain to students that this type of graph helps scientists to make predictions.
F. Ask: How could we predict how many swings a pendulum that is 50 cm long would make? *Show students how to find 50 on the X-axis, go straight up until they hit the line, and then cross over to the Y-axis to find the approximate number of swings. Have them record this on the data table on their activity sheet.*
G. Have students complete the same process for 65 cm and 80 cm as you model the process for them.

Teachers may want to do the actual testing of these three lengths as a demonstration. Students should be able to grasp the power of the graph in its ability to predict the future motion. Test the 50 cm, 65 cm, and 80 cm lengths. Have students record the actual values on their data table.

Have students answer the following on the student activity sheet:

- Explain HOW you used the graph to predict the number of swings that the pendulum would make. *We graphed several data points on the graph. We drew a “line of best fit” through as many of the data points as we could. We then used the line to help us make predictions. We found the length of string on the X-axis, followed it up until we hit the line, and then went over to the Y-axis. We read the place on the Y-axis to find the predicted number of swings.*

Have students complete the final formative assessment that is included on the student activity sheet. This could also be used separately as an exit ticket.

- *The correct answer is B. Based on the evidence from the experiments, mass and release angle do not have an effect on the number of swings. However, making the string shorter should increase the number of swings.*

Citations and Resources

Lesson adapted from:
https://www.wccusd.net/cms/lib/CA01001466/Centricity/domain/60/lessons/grade%205%20lessons/PendulumAndGraphingV1.pdf

Forty-five New Force and Motion Assessment Probes
Volume 1 of Uncovering student ideas in physical science, Page Keeley by Page Keeley and Rand Harrington

Galileo Clip Art was purchased from VectorToons.com
http://tracker.cci.fsu.edu/teacher/classroom-modules/module-3/m3lesson-1/

Rather than listen to a Sunday service in 1581, Galileo Galilei studied a chandelier hanging overhead in the huge cathedral in Pisa, Italy. Air currents flowing through the lofty building moved the chandelier from side to side, back and forth. Sometimes the chandelier moved gently; sometimes it swung in a wide arc. No matter what the size of its swing, it seemed to Galileo that the chandelier kept steady time.

One, two, three beats.....

There were no clocks or watches in those days. To time the chandelier's swings, Galileo felt for the pulse in his wrist. He counted the pulse beats. One, two, three beats for one swing. One, two, three beats for another.

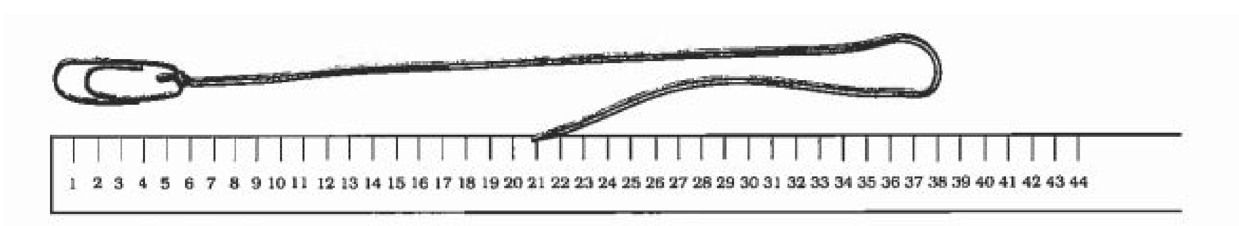
Right after the service, Galileo raced home. He suspended a weight from a long string to create a pendulum and then he pulled the weight back a short distance, released it, and timed its swing. He tried it again, this time pulling the weight back farther before releasing it. Galileo tried other experiments with his pendulum. He discovered that the length of string, amount of weight, and other factors all had some predictable relationship to the time of a pendulum's swing. Eventually, Galileo discovered how to use a pendulum to create the first "pendulum clock."

We can recreate Galileo's experiments by making and using a simple pendulum to discover the same <u>predictable</u> relationships that he did!

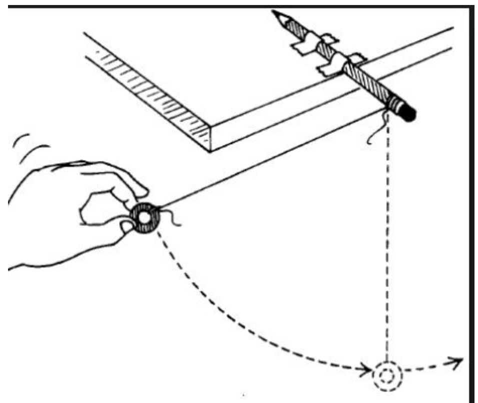
I. Let's build a pendulum. Here's what you will need:

string (about 50 cm)	metric meter stick
1 paper clip	1 penny
masking tape	1 pencil

A. Tie one end of the string securely to the paper clip.
B. Measure exactly 38 cm from the tip of the paper clip along the string. Fold the string back at exactly the 38 cm mark.
C. Put a tiny piece of masking tape around the string to make a loop. The loop should be large enough to hang over a pencil. Remeasure to make sure the pendulum measures 38 cm from the tip of the paper clip to the top of the loop.



D. Clip a penny in the paper clip.
E. Tape an unsharpened pencil onto a flat desk. Make sure the pencil extends about halfway out over the edge. Hang the loop of string onto the pencil. You have made a pendulum!



II. Let's get started with **Experiment #1**! How many times do you think your pendulum will swing in 20 seconds? How can we find out?

Trial	Length of String	Time Period	Number of Pennies	Release Angle (Degrees)	Number of Swing Cycles
1	38 cm	20 seconds	1	0	
2	38 cm	20 seconds	1	0	
3	38 cm	20 seconds	1	0	

Mean Number of Swings: ___________

The results in the table above will be the starting point for our experiments. We'll use it as a standard of comparison for our results.

How did your mean compare with your classmates?

What could we change in our pendulum system that might change the number of swings in 20 seconds? Anything that we can change in a system that might affect the outcome is called a *variable*. When scientists conduct experiments, it is important to only test ONE variable at a time.

Experiment #2: Let's see how the number of swings is affected when we change the starting angle of release.

Independent Variable: ___________________________________

Dependent Variable: _____________________________________

Length of String	Time Period	Number of Pennies	Release Angle (degrees)	Number of Swings
38 cm	20 seconds	1	0	
38 cm	20 seconds	1	20	
38 cm	20 seconds	1	40	

Based on the evidence that you have collected, how does the angle of release affect the number of swings of the pendulum?

Using the pattern in your data, predict the number of swings that will result from a release angle of 60 degrees. Explain HOW you used the data to make your prediction.

AFTER you make your prediction, use your pendulum to find the actual number of swings and add that data to the table.

Length of String	Time Period	Number of Pennies	Release Angle (Degrees)	Predicted Number of Swings	Actual Number of Swings
38 cm	20 seconds	1	60		

How close was your predicted value to the actual value?

Experiment #3: Now let's see how the number of swings is affected when <u>we change the mass of the "bob" (number of pennies).</u>

Independent Variable: ___________________________________

Dependent Variable: _____________________________________

Length of String	Time Period	Number of Pennies	Release Angle (degrees)	Number of Swings
38 cm	20 seconds	1	0	
38 cm	20 seconds	2	0	
38 cm	20 seconds	3	0	

Based on the evidence that you have collected, how does the mass of the bob affect the number of swings of the pendulum?

Using the pattern in your data, predict the number of swings that will result from a mass of **four** pennies. Explain HOW you used the data to make your prediction.

AFTER you make your prediction, use your pendulum to find the actual number of swings and add that data to the table.

Length of String	Time Period	Number of Pennies	Release Angle (Degrees)	Predicted Number of Swings	Actual Number of Swings
38 cm	20 seconds	4	0		

How close was your predicted value to the actual value?

Experiment #4: Let's do one last experiment. Let's see how the number of swings is affected when <u>we change the length of the string.</u>

Independent Variable: ____

Dependent Variable: ____

We will use our 38 cm pendulum as a standard of comparison. This is called a *control*. A number line has been placed on the wall of the classroom. Each number represents a different number of pendulum swings. Locate the mean number of swings that you recorded in Experiment #1. Hang your pendulum on the number that is closest to your mean number of swings.

Your group will now be assigned a new length of string to test. Build a new pendulum with this length of string. You will record your data in the table below.

Length of String	Time Period	Number of Pennies	Release Angle (degrees)	Number of Swings
	20 seconds	1	0	
	20 seconds	1	0	
	20 seconds	1	0	

Mean Number of Swings: _____________

A. Hang your pendulum on the number line on the number that represents the mean number of swings that you recorded.
B. Also record the number of swings on the T-chart that has been set up in the classroom so that other students will be able to see your result.
C. After ALL the results have been posted in the classroom, answer the following.

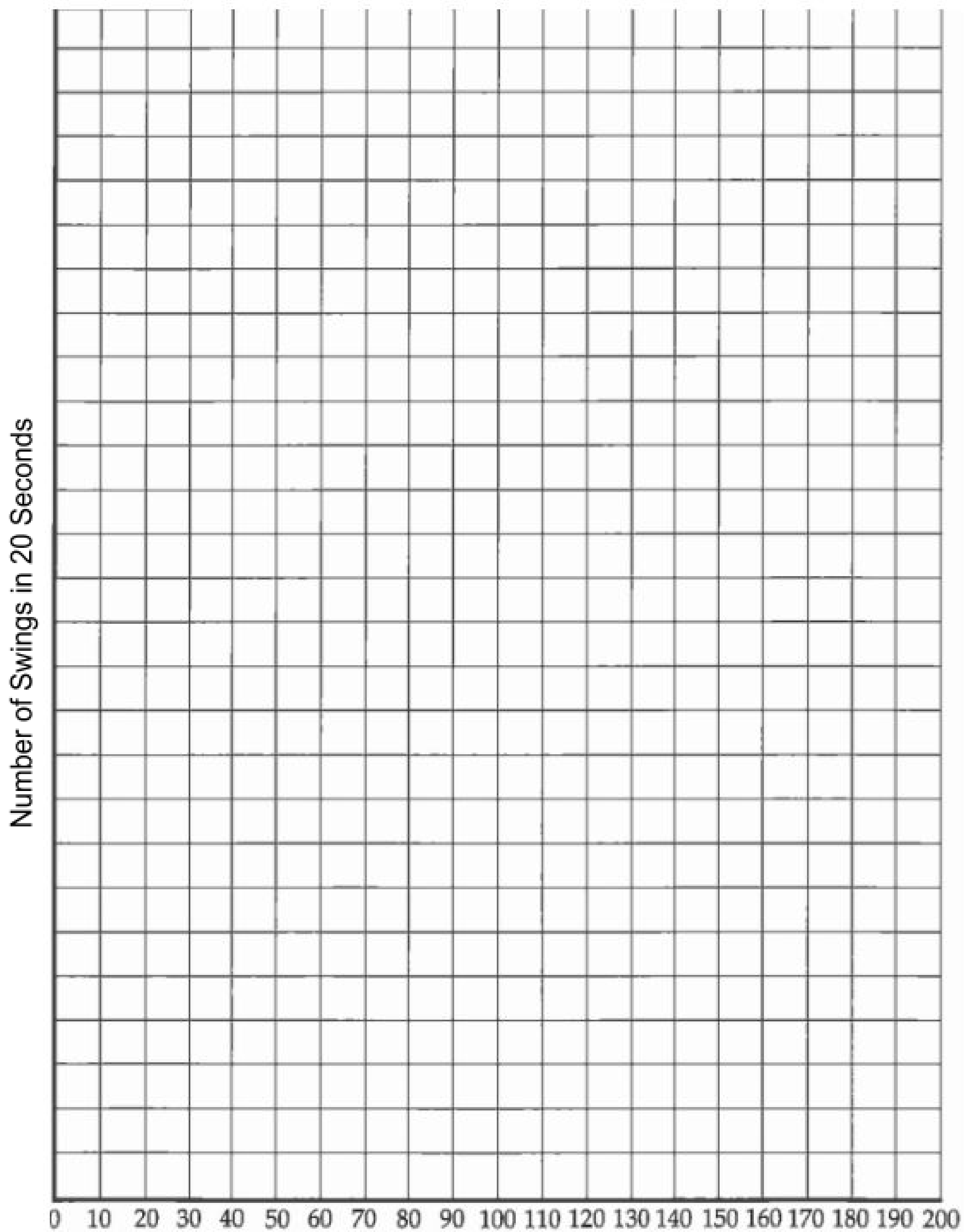
Describe the relationship between the length of the string and the number of swings of the pendulum.

D. Record the class results in the T-chart below.

Length of String	Number of Swings

This is one way of representing the data from our experiment. However, graphs often help us look at data in an even more useful way. Use the graph on the next page to plot the points from the T-chart above.

Effect of Length of String on the Number of Swings in 20 Seconds



Length of String (cm)

E. Let's use the graph to predict how many swings the pendulum would make at lengths that we have not tested. Then, we'll see how accurate our results are.

Length of String	Time Period	Number of Pennies	Release Angle (degrees)	Predicted Swings According to Graph	Actual Number of Swings
50 cm	20 seconds	1	0		
65 cm	20 seconds	1	0		
80 cm	20 seconds	1	0		

F. Explain HOW you used the graph to predict the number of swings that the pendulum would make.

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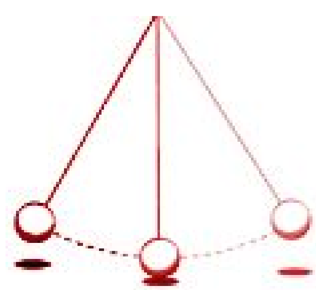
Let's see if you have discovered the same relationship as Galileo did hundreds of years ago.

Gusti made a pendulum by tying a string to a small bob. He pulled the bob back and counted the number of swings the pendulum made in 30 seconds. He wondered what he could do to increase the number of swings made by the pendulum. If Gusti can change only one thing to make the pendulum swing more times in 30 seconds, what should he do? Circle what you think will make the pendulum swing more times.



A. Lengthen the string.

B. Shorten the string.

C. Change to a heavier bob.

D. Change to a lighter bob.

E. Pull the bob back farther.

F. Don't pull the bob back as far.

G. None of the above. All pendulums swing the same number of times.

Explain your thinking. What rule or reasoning did you use to select your answer?

Citations and Resources

Lesson adapted from:
https://www.wccusd.net/cms/lib/CA01001466/Centricity/domain/60/lessons/grade%205%20lessons/PendulumAndGraphingV1.pdf

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Tab page front

Label: Developing and Using Models

TN Department of Education

Developing and Using Models

Tennessee Academic Standards for Science

Teacher Guide for Grade 5

Standard
5.ESS1.4 Explain the cause and effect relationship between the positions of the sun, earth, and moon and resulting eclipses, position of constellations, and appearance of the moon.

Tennessee Academic Standards for Science: Page 43

Three-dimensional Learning Performance for Lesson
Students will develop and use models* in order to show the positions of the sun, earth, and moon during solar and lunar eclipses** highlighting the cause and effect relationship between the positions and resulting eclipses.***

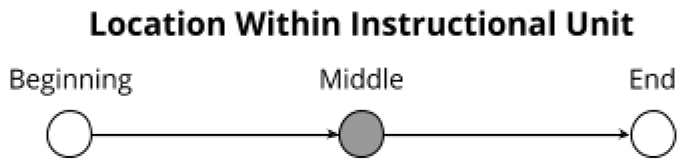
Science and Engineering Practice for Lesson
*Developing and Using Models**
Students will make observations based on both lunar and solar eclipse images and video clips. Based on these observations, students will then use simple materials to develop a model that accurately shows the positions of the Earth, moon, and sun during each type of eclipse. Students will also analyze the effectiveness of the model for accuracy and limitations.

Disciplinary Core Idea for Lesson
*Earth and the Solar System***
Gravity holds Earth in orbit around the sun, and it holds the moon in orbit around Earth. The pulls of gravity from the sun and the moon cause the patterns of ocean tides. The moon's and sun's positions relative to Earth cause lunar and solar eclipses to occur. The moon's monthly orbit around Earth, the relative positions of the sun, the moon, and the observer and the fact that it shines by reflected sunlight explain the observed phases of the moon.

A Framework for K–12 Science Education: Page 175

Crosscutting Concept for Lesson
*Cause and Effect****
A solar eclipse occurs when our view of the sun is being blocked by the moon. For this to happen, the moon has to be between the Earth and the sun. In contrast, a lunar eclipse occurs when the moon passes through the earth's shadow in space. For that to happen, the earth has to be between the sun and the moon. In both cases, the positions of the bodies (cause) result in a specific type of eclipse (effect). Eclipses only occur when there is an exact alignment of the bodies.

Prior Knowledge



- Concepts that should be covered before this lesson:
    - Scale of the Earth–sun–moon system
    - Complex motion of the earth–sun–moon System
    - Shadows
    - Phases of the moon
    - Using a model to explain how the orbit of the earth and sun cause observable patterns: day and night, changes in length and direction of shadows over a day
- This lesson covers portions of standard 5.ESS1.4:
    - Explain the cause and effect relationship between the positions of the sun, Earth, and moon and resulting eclipses.

Materials

- https://www.youtube.com/watch?v=lcRp1jKJmJU
- https://www.youtube.com/watch?v=rVE8PFYlwSM&feature=youtu.be
- Google Slide presentation (Eclipse Images)
- Clay (approximately 1 oz per group)
- Meter stick (1 per group)
- Toothpicks (2 per group)
- Binder clips (2 per group)
- Large piece of white poster board (1 per group)
- Light source (flashlight, 1 per group)

Lesson Sequence and Instructional Notes

Teacher Background Information

One of the hardest parts about teaching how eclipses work is to be clear about the difference between a solar eclipse and a lunar eclipse. A solar eclipse is when our view of the sun is being blocked by the moon. For this to happen, the moon has to be between the Earth and the sun. In contrast, a lunar eclipse occurs when the moon passes through the Earth's shadow in space. For that to happen, the Earth has to be between the sun and the moon. In both cases, the eclipse is caused by the alignment of those three bodies, so it can be easy to confuse which alignment causes which type of eclipse.

Students might also wonder why eclipses don't occur more frequently. Eclipses would happen more frequently if it were not for the fact that the moon's orbit around the Earth is tilted about five degrees from the Earth's orbit around the sun. That means that each month, the alignment of the sun-Earth-moon system comes close to creating both a lunar eclipse at full moon and a solar eclipse at new moon. But the exact alignment is more rare than that, with partial or total solar eclipses visible from somewhere on Earth on average about 2.4 times per year, and that somewhere doesn't always even reach a continent. Partial or total lunar eclipses happen about 1.5 times per year.[1] Though the underlying geometry is difficult to verbalize to students, the strength of scientific models to make these challenging mental models concrete.

Inform the students that today they will be learning about something called an eclipse.

- Ask: Has anyone ever heard the word "eclipse?" How have you heard the word used?
- Tell the students that an eclipse takes place when one heavenly body, such as a moon or planet, moves into the shadow of another heavenly body. There are two types of eclipses on Earth: an eclipse of the moon (lunar) and an eclipse of the sun (solar).

Tell students that we are going to study each type of eclipse one at a time. Their goal will be to make observations of each type of eclipse and then to use those observations in order to develop a model to demonstrate each type of eclipse.

Display the first slide of the Google presentation. Direct students' attention to their student activity guide, which shows a cartoon of a lunar eclipse. Read the caption to the students and ask them to complete the accompanying question: The cartoon on the right is a humorous look at a lunar eclipse. Based on the cartoon, explain what you think happens during a lunar eclipse.

Share out student responses to elicit student ideas about what is occurring during a lunar eclipse.

Direct students to the next portion of the student activity sheet, the observation table. Tell the students that you are going to show them several images and a video clip of an actual lunar eclipse. Go through slides three through six and allow students to record observations on their activity sheet. Note that slide six has an embedded video of a lunar eclipse. Teachers will want to preview the video first and may want to only show the video and NOT the audio.

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[1] *From: Modeling a Solar Eclipse - National Air and Space Museum*

Ask students to share their observations. Teachers might want to write these so that all students can see the observations of other students. At this point of the lesson, it is important to just have students actively observing as they try to figure out exactly what is happening to cause the observations that they see.

Possible student observations might include:

- *The moon changes color from gray to reddish/orange.*
- *The moon is moving across from right to left and takes (in this example) about three to four hours to do so.*
- *There is something called an "umbra" and something called a "penumbra." When the moon is in the umbra it turns darker.*
- *It appears in one image as if there is a shadow crossing over the moon but the moon isn't entirely covered yet.*
- *It is a full moon.*
- *The video clearly shows a shadow moving in front of the moon.*

Teachers may want to use this opportunity to ask additional questions to guide students toward a possible model.

Probing teacher questions:

- Why do you think the moon changes color during a lunar eclipse? *As the moon moves into the Earth's shadow, most of the sunlight is blocked. However, since red is the longest wavelength of light, it is refracted around and through the earth's atmosphere and reaches the surface of the moon. The moon reflects this back as "red" to our eyes.*
- What about the sunlight? Is it completely blocked? Is the earth big enough to block all the sunlight? *The Earth can block most of the sunlight during a total solar eclipse, causing the moon to appear dark and then possibly reddish.*
- What is making the shadow? *The Earth is making the shadow because it is blocking the sunlight. The Earth is in between the sun and the moon.*
- What is the phase of the moon during a lunar eclipse? *It must be a full moon.*
- Where is the moon when it is a full moon? *In a position so that the entire side of the moon facing the earth reflects all the sunlight.*
- Where is the moon during a lunar eclipse? *In the same position. In other words, lunar eclipses can only occur during a full moon.*

Tell students that you want them to work in small groups to create a model of a lunar eclipse. *If students need more support before attempting the model, informational text on lunar eclipses is included in the lesson materials and can be read before proceeding to the next step.*

Provide students with the materials for the models, but allow them to decide how to use the materials. Teachers will want to turn the lights out in the classroom so that minimal extra light will interfere. Teachers should circulate throughout the room to support students as needed. Teachers can initial the student activity sheet when a successful model has been developed.

Students will need to demonstrate the following in their model:

- Size of moon in comparison to the Earth: diameter of the moon is about one-quarter of the Earth's diameter
- Distance between Earth and the moon: Earth-moon distance is about 30 Earth diameters
- Lunar eclipses occur only during a full moon
- The Earth's shadow should cover the moon

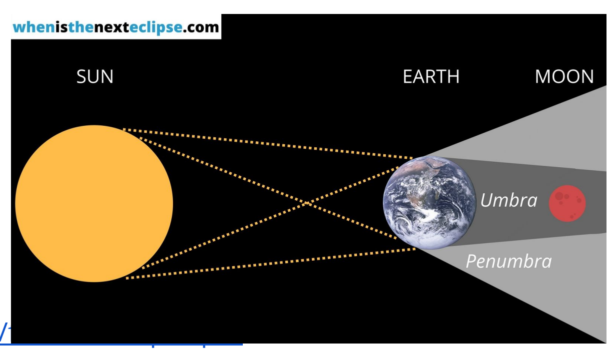
Teacher Information: To make a successful model of a lunar eclipse using these materials, the procedure[2] would be as follows:
These instructions can be adjusted in a manner that allows students to demonstrate some grade-level math reasoning skills during the construction of their models.

1. Make a clay ball that is 1" diameter. This will represent the Earth in your model.
2. Make a smaller clay ball that is ¼" diameter. This will represent the moon, which is about ¼ the diameter of Earth.
3. Stick a toothpick approximately halfway through each ball.
4. Use one binder clip to attach the toothpick that holds the larger ball to the yardstick, very close to the beginning of the yardstick.
5. Use a binder clip to attach the toothpick that holds the smaller ball to the yardstick at the 30" mark. The distance from the Earth to the moon is approximately 30 times the Earth's diameter, so this creates a good model of the Earth-moon system.
6. Align your Earth-and-moon model with the sun (flashlight) so that the large ball blocks the light from the small ball. The only way that this can be accomplished is for the earth to be in between the sun and the moon. The phase of the moon would be a full moon.
7. Students can place a piece of posterboard behind the moon to show the Earth's shadow.

Ask students to complete the next section on the student activity sheet, which asks them to describe their successful model using both words and pictures.

- *Students should note that the Earth had to be between the moon and the sun in order to block the light. The moon is a full moon.*

This image is also included on the Google slide presentation for teachers to share with students AFTER they have attempted their models.



[2] *Directions from* https://airandspace.si.edu/sites/default/

Display slide eight of the Google presentation. Direct students' attention to their student activity guide which shows a cartoon of a solar eclipse. Read the caption to the students and ask them to complete the accompanying question: The cartoon on the right is a humorous look at a solar eclipse. Based on the cartoon, explain what you think happens during a solar eclipse.

Share out student responses to elicit student ideas about what is occurring during a solar eclipse.

Direct students to the next portion of the student activity sheet, the observation table. Tell the students that you are going to show them several images and a video clip of an actual solar eclipse. Go through slides 9-12 and allow students to record observations on their activity sheet. Note that slide 12 has an embedded video of a solar eclipse. Teachers will want to preview the video first and may choose to mute the audio.

Ask students to share their observations. Teachers might want to write these so that all students can see the observations of other students. At this point of the lesson, it is important to just have students actively observing as they try to figure out exactly what is happening to cause the observations that they see.

Possible observations might include:

- *A shadow seems to move across and block the light from the sun.*
- *When the sun is blocked, you can still see a "halo" of light sticking out.*
- *In one image, a tiny bit of orange/red appears around the edge of the sun.*
- *The video points out that it is the moon's shadow that is entering and covering up the sun.*
- *The video notes that it gets colder.*
- *The people in the video have special glasses on.*
- *As the moon continues its motion, it moves out from in front of the sun.*

Teachers may want to use this opportunity to ask additional questions to guide students toward a possible model.

Probing teacher questions:

- How can the moon block the sun if the moon is so much smaller? *At this point in time, the moon's distance from the Earth is such that it can completely cover the sun if the position is right. The moon is much closer to the Earth and so can line up to cover the sun during a total solar eclipse.*
- What must the phase of the moon be during a total solar eclipse? *It must be a new moon.*

- What has to be the position of the moon and the Earth during a new moon? *The moon would be between the Earth and the sun. The side of the moon facing the Earth would not reflect any sunlight and so would appear dark to us on the Earth.*
- What do you think the "halo" is? *It's the sun's corona, or outermost layer of its atmosphere. This is there ALL the time but is normally not visible to us due to the intensity of light from the sun.*

Tell students that you want them to work in small groups to create a model of a solar eclipse. *If students need more support before attempting the model, informational text on solar eclipses is included in the lesson materials and can be read before proceeding to the next step.*

Provide students with the materials for the models but allow them to decide how to use the materials. Teachers will want to turn the lights out in the classroom so that minimal extra light will interfere. Teachers should circulate throughout the room to support students as needed. Teachers can initial the student activity sheet when a successful model has been developed. A successful model should include:

- Size of moon in comparison to the Earth: diameter of the moon is about one-quarter of the earth's diameter
- Distance between Earth and the moon: Earth–moon distance is about 30 Earth diameters
- Lunar eclipses occur only during a full moon
- The Earth's shadow should cover the moon

Teacher Information: To make a successful model of a solar eclipse using these materials, procedure[3] would be as follows:

1. Make a clay ball that is 1" diameter. This will represent the Earth in your model.
2. Make a smaller clay ball that is ¼" diameter. This will represent the moon, which is about ¼ the diameter of Earth.
3. Stick a toothpick approximately halfway through each ball.
4. Use one binder clip to attach the toothpick that holds the larger ball to the yardstick, very close to the beginning of the yardstick.
5. Use a binder clip to attach the toothpick that holds the smaller ball to the yardstick at the 30" mark. The distance from the earth to the moon is approximately 30 times the earth's diameter, so this creates a good model of the Earth-moon system.
6. Align your Earth-and-moon model with the sun (flashlight) so that the small ball blocks the light from the large ball. Students should observe that the moon creates a small shadow on the surface of the Earth. Only people on the Earth who are in the shadow of the moon would observe the total solar eclipse. The only way that this can be accomplished is for the moon to be between the sun and the Earth.

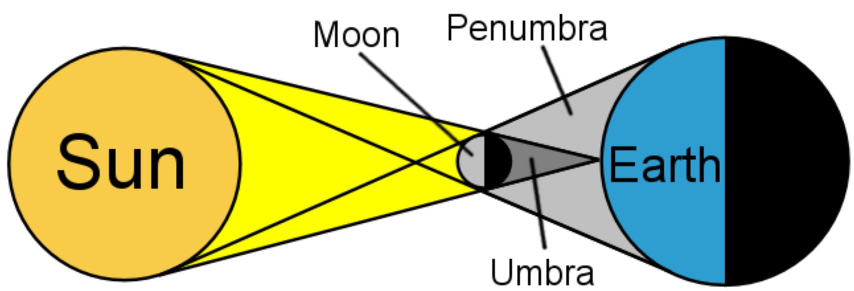
Ask students to complete the next section on the student activity sheet, which asks them to describe their successful model using both words and pictures.

[3] *Directions from* https://airandspace.si.edu/sites/default/files/iss-eclipse.pdf

Students should note that a total solar eclipse occurs only during a new moon. The moon has to be between the Earth and the sun and lined up in such a way that the moon's shadow crosses the Earth.

This image is included on the Google Slide presentation for teachers to share with their students AFTER they have attempted to make their models.

Tell students to now complete the last section of the student activity sheet. This section asks students to evaluate their models.



A. How accurate are your eclipse models? Describe both the accuracy and the limitations of your eclipse models:
   - Accuracy of Lunar Eclipse Model:
     - *The positions of the sun, Earth, and moon are correct*
     - *The shadow of the Earth covers the moon*
   - Limitations of Lunar Eclipse Model
     - *Can't actually show the moon turning "red"*
     - *Doesn't show the continual motion of the objects*
   - Accuracy of Solar Eclipse Model:
     - *Positions of the sun, Earth, and moon are correct*
     - *The shadow of the moon is shown on the surface of the Earth*
   - Limitations of Solar Eclipse Model:
     - *Does not show the sun's corona*
     - *Does not show the continual motion of the objects*

B. Describe a DIFFERENT way to create a model of an eclipse.
   Answers will vary.

C. Write two questions that you still have about solar and/or lunar eclipses.
   - Question 1:
   - Question 2:
   - Were you able to answer the questions based on your model? Explain.
   - *Students will note that the model is useful to show how the eclipses occur but does not answer many other questions that they might have.*

Have a whole class discussion to share out the accuracy and limitations of the models. Discuss the usefulness of the model as well as the fact that some questions can't be answered with this model.

If teachers feel that additional explicit information is needed, this video clip describes the difference between a lunar and solar eclipse, and can be used as needed.

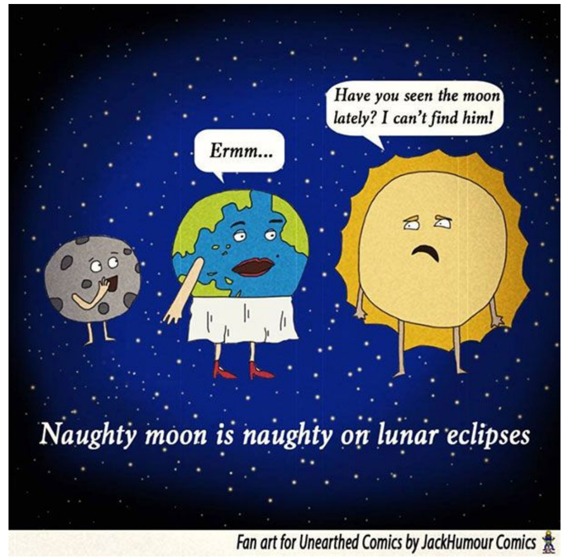
Citations and Resources

Cartoons from UnEarthed Comics (copyright permission granted for teacher use at website)
https://www.nasa.gov/audience/forstudents/5-8/features/nasa-knows/index.html

https://www.youtube.com/watch?v=rVE8PFYlwSM&feature=youtu.be
https://airandspace.si.edu/sites/default/files/iss-eclipse.pdf

Lunar and Solar Eclipses

1. The cartoon on the right is a humorous look at a lunar eclipse. Based on the cartoon, explain what you think happens during a lunar eclipse.



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2. Let's learn more about lunar eclipses. Your teacher will show you images and a video of a recent lunar eclipse. As you view the images, write down three observations about a lunar eclipse.

Observation #1	
Observation #2	
Observation #3	

3. Can we construct a 3D physical model of the Earth–sun–moon system based on our observations of a lunar eclipse?

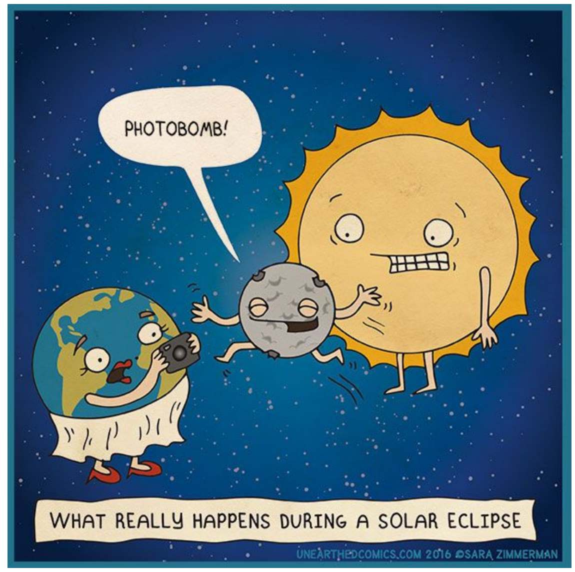
Using the materials provided by your teacher, work with your group to construct your 3D model of a lunar eclipse. Your model should demonstrate the following:

- Size of the moon in comparison to the Earth: diameter of the moon is about one-quarter of the Earth's diameter
- Distance between Earth and the moon: Earth-Moon distance is about 30 Earth diameters
- Lunar eclipses occur only during a full moon
- The Earth's shadow should cover the moon.

Demonstrate your successful model for your teacher. Teacher Initials:

4. In the space below, describe in words and pictures, your model of a lunar eclipse. Label the sun, moon, and Earth. Include a sketch of the path of light as well as the shadow created.

5. The cartoon on the right is a humorous look at a solar eclipse. Based on the cartoon, explain what you think happens during a solar eclipse.



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6. Let's learn more about solar eclipses. Your teacher will show you some images and a video of a recent solar eclipse. As you view the images, write down three observations about a solar eclipse.

Observation #1	
Observation #2	
Observation #3	

7. Can we construct a 3D physical model of the Earth–sun–moon system to recreate our observations of a solar eclipse? Your model should demonstrate the following:

- Size of the moon in comparison to the Earth: diameter of the moon is about one-quarter of the Earth's diameter
- Distance between Earth and the moon: Earth–moon distance is about 30 Earth diameters
- Solar eclipses occur only during a new moon
- The moon's shadow should fall on the Earth

Demonstrate your successful model for your teacher. Teacher Initials:

8. In the space below, describe in words and pictures your model of a solar eclipse. Label the sun, moon, and Earth. Include a sketch of the path of light as well as the shadow created. Label both the umbra and the penumbra.

9. Let's evaluate your models.

A. How accurate are your eclipse models? Describe both the accuracy and the limitations of your eclipse models:

Accuracy of Lunar Eclipse Model:

Limitations of Lunar Eclipse Model:

Accuracy of Solar Eclipse Model:

Limitations of Solar Eclipse Model:

B. Describe a DIFFERENT way to create a model of an eclipse.

C. Work with your group to write two questions that you still have about solar and/or lunar eclipses.

Question 1:

Question 2:

Would you be able to answer the questions based on your model? Explain.

What Is a Lunar Eclipse?

The moon moves in an orbit around Earth, and at the same time, Earth orbits the sun. Sometimes Earth moves between the sun and the moon. When this happens, Earth blocks the sunlight that normally is reflected by the moon. (This sunlight is what causes the moon to shine.) Instead of light hitting the moon's surface, Earth's shadow falls on it. This is an eclipse of the moon -- a lunar eclipse. A lunar eclipse can occur only when the moon is full.

A lunar eclipse can be seen from Earth at night. There are two types of lunar eclipses: total lunar eclipses and partial lunar eclipses.

A total lunar eclipse occurs when the moon and the sun are on exact opposite sides of Earth. Although the moon is in Earth's shadow, some sunlight reaches the moon. The sunlight passes through Earth's atmosphere, which causes Earth's atmosphere to filter out most of the blue light. This makes the moon appear red to people on Earth.

A partial lunar eclipse happens when only a part of the moon enters Earth's shadow. In a partial eclipse, Earth's shadow appears very dark on the side of the moon facing Earth. What people see from Earth during a partial lunar eclipse depends on how the sun, Earth and moon are lined up.

A lunar eclipse usually lasts for a few hours. At least two partial lunar eclipses happen every year, but total lunar eclipses are rare. It is safe to look at a lunar eclipse.

This article is part of the NASA Knows! (Grades 5-8) series.

What Is a Solar Eclipse?

Sometimes when the moon orbits Earth, it moves between the sun and Earth. When this happens, the moon blocks the light of the sun from reaching Earth. This causes an eclipse of the sun, or solar eclipse. During a solar eclipse, the moon casts a shadow onto Earth.

There are three types of solar eclipses.

The first is a total solar eclipse. A total solar eclipse is only visible from a small area on Earth. The people who see the total eclipse are in the center of the moon's shadow when it hits Earth. The sky becomes very dark, as if it were night. For a total eclipse to take place, the sun, moon and Earth must be in a direct line.

The second type of solar eclipse is a partial solar eclipse. This happens when the sun, moon and Earth are not exactly lined up. The sun appears to have a dark shadow on only a small part of its surface.

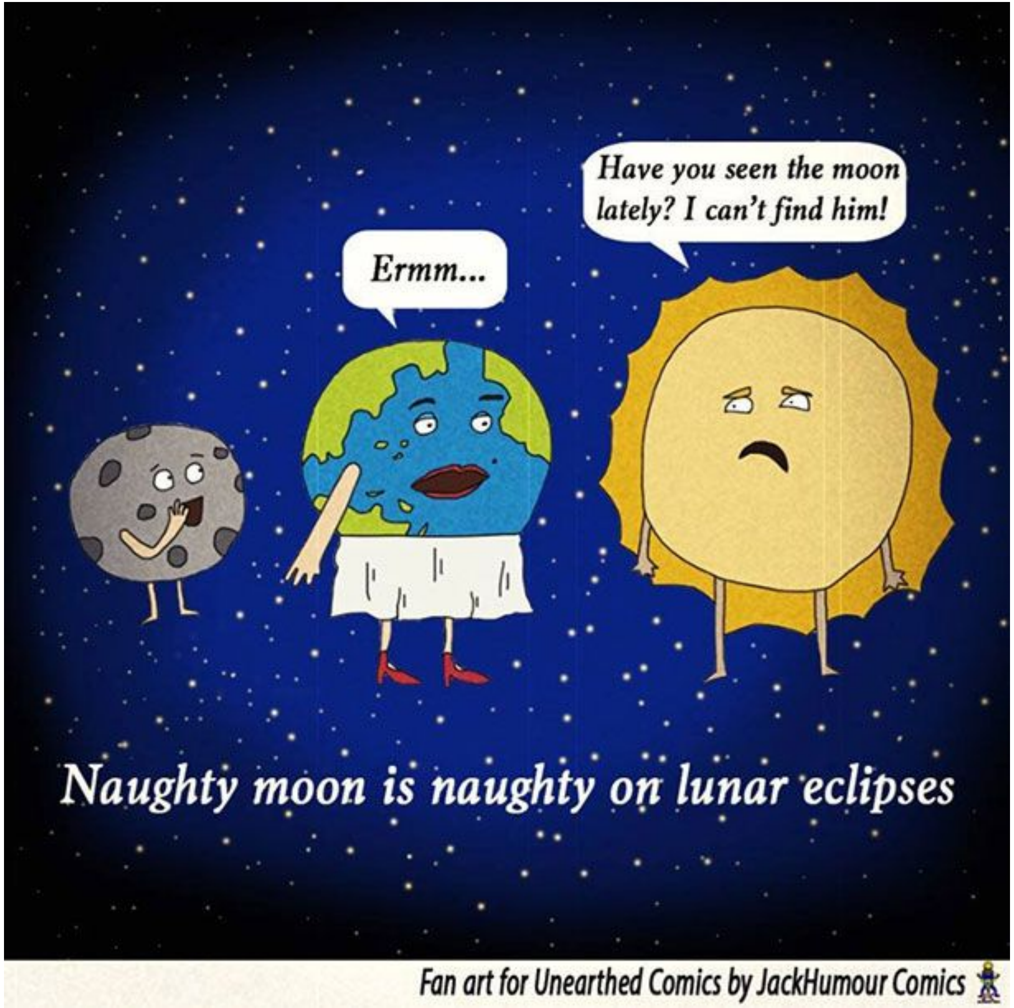
The third type is an annular (ANN you ler) solar eclipse. An annular eclipse happens when the moon is farthest from Earth. Because the moon is farther away from Earth, it seems smaller. It does not block the entire view of the sun. The moon in front of the sun looks like a dark disk on top of a larger sun-colored disk. This creates what looks like a ring around the moon.

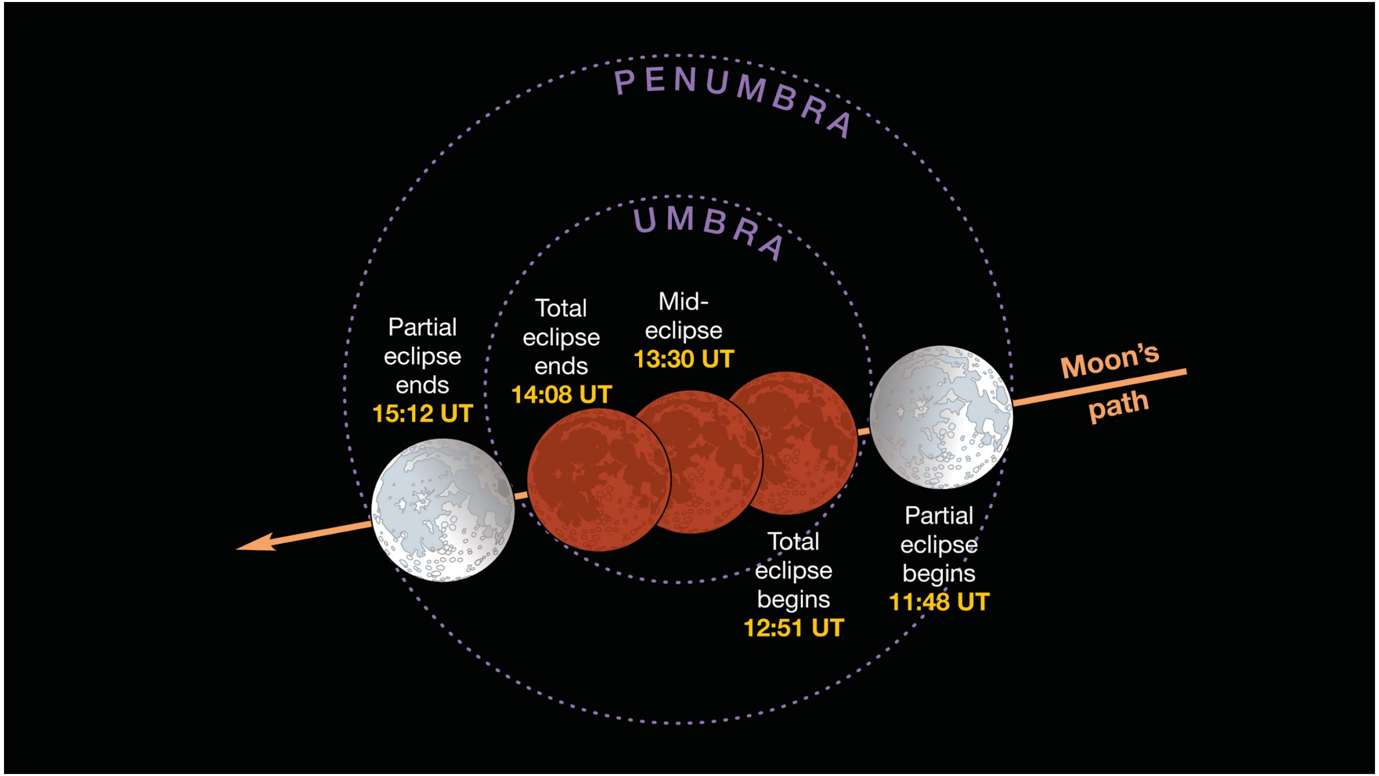
During a solar eclipse, the moon casts two shadows on Earth. The first shadow is called the umbra (UM bruh). This shadow gets smaller as it reaches Earth. It is the dark center of the moon's shadow. The second shadow is called the penumbra (pe NUM bruh). The penumbra gets larger as it reaches Earth. People standing in the penumbra will see a partial eclipse. People standing in the umbra will see a total eclipse.

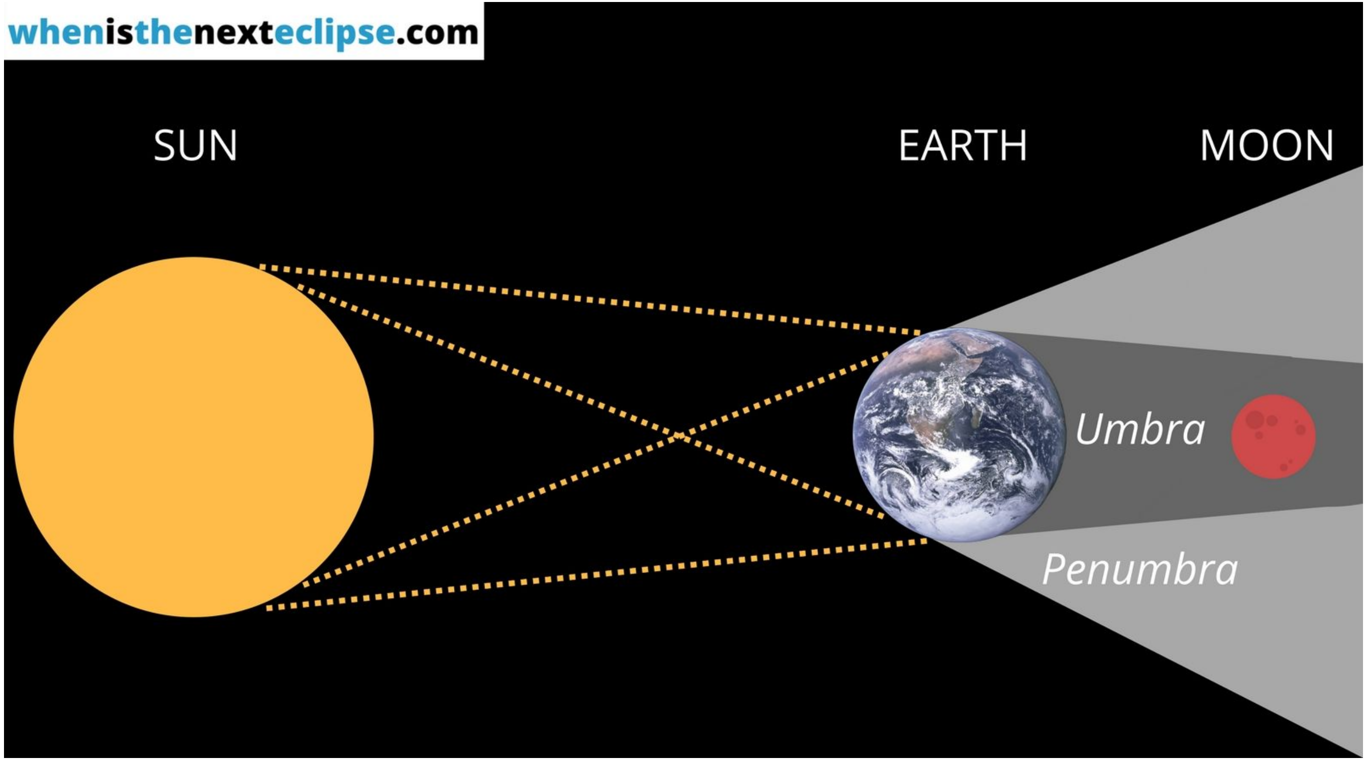
Solar eclipses happen once every 18 months. Unlike lunar eclipses, solar eclipses only last for a few minutes.

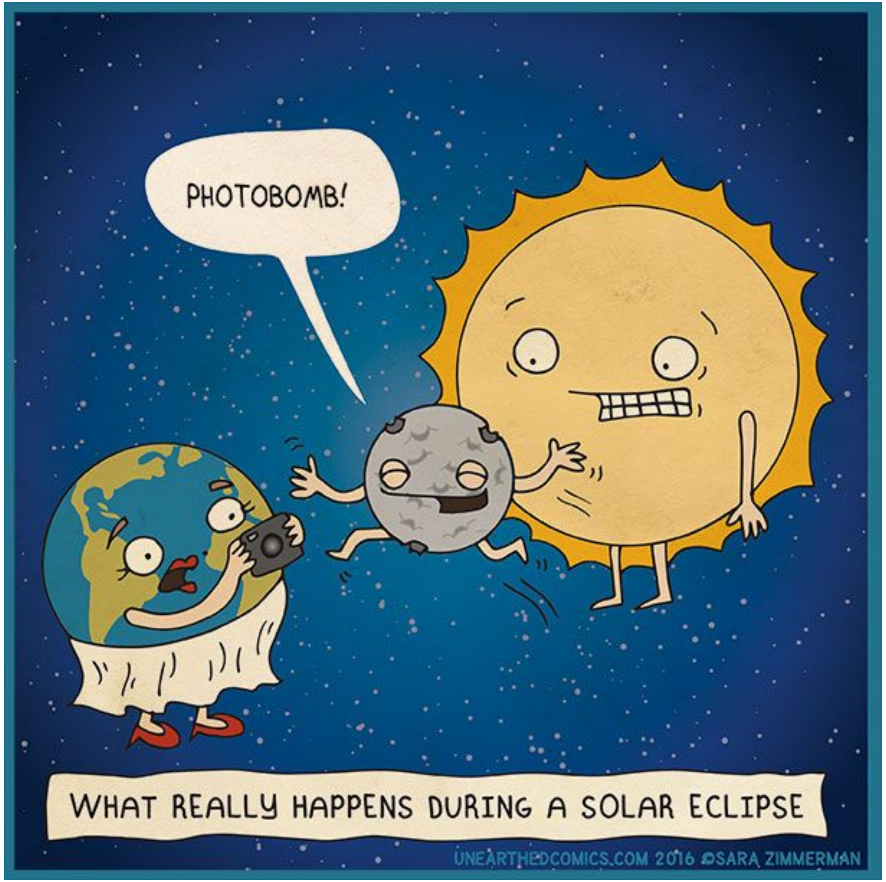
This article is part of the NASA Knows! (Grades 5-8) series.

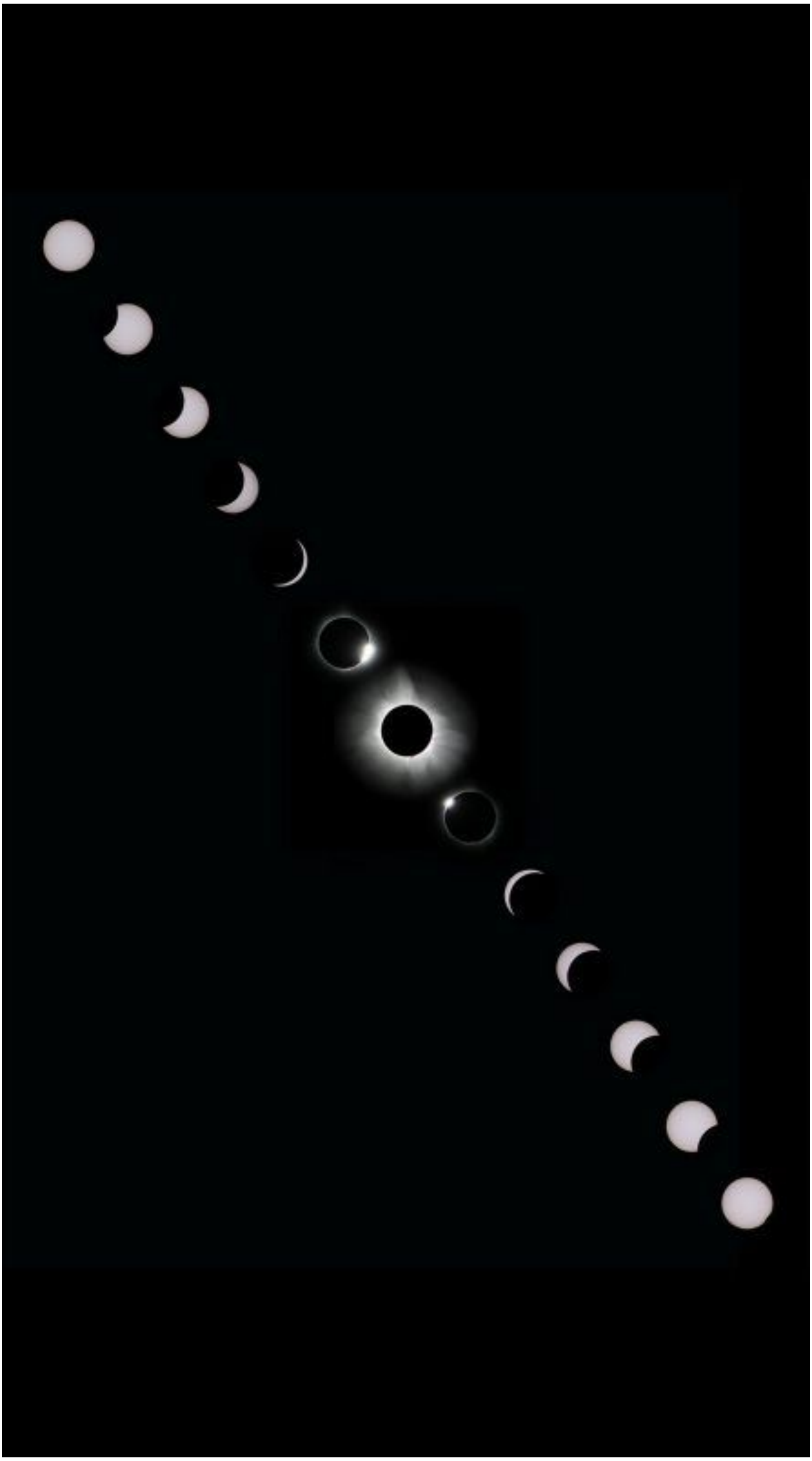
Eclipse Images

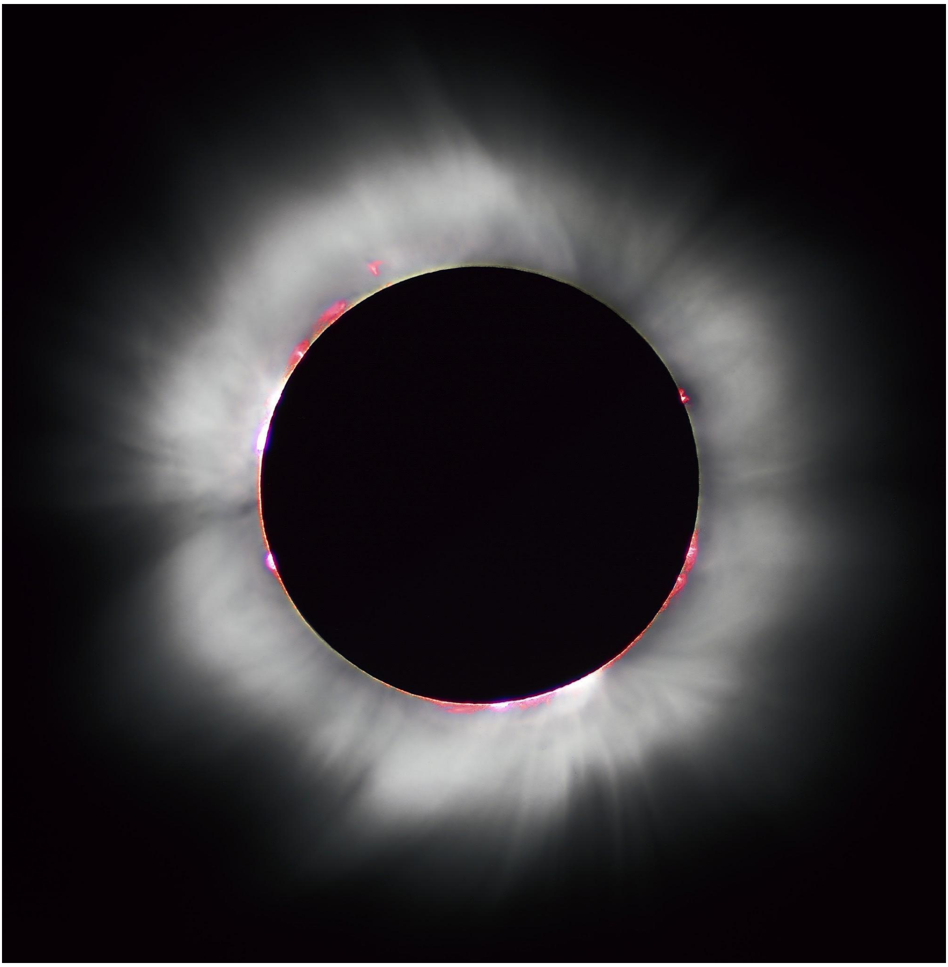

Have you seen the moon lately? I can't find him!
Ermm...
Naughty moon is naughty on lunar eclipses
Fan art for Unearthed Comics by JackHumour Comics

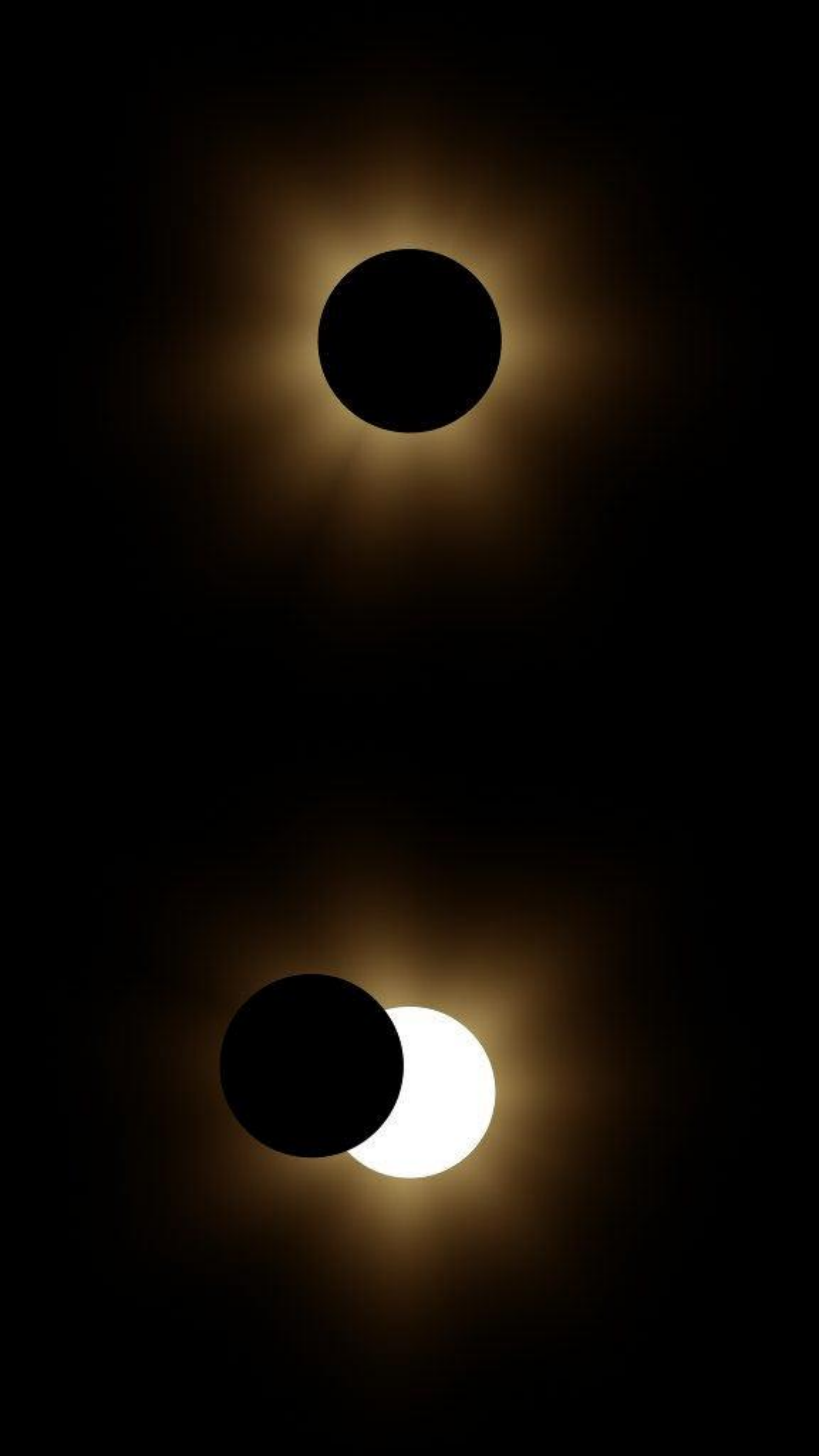

PENUMBRA
UMBRA
Partial eclipse ends 15:12 UT
Total eclipse ends 14:08 UT
Mid-eclipse 13:30 UT
Total eclipse begins 12:51 UT
Partial eclipse begins 11:48 UT
Moon's path

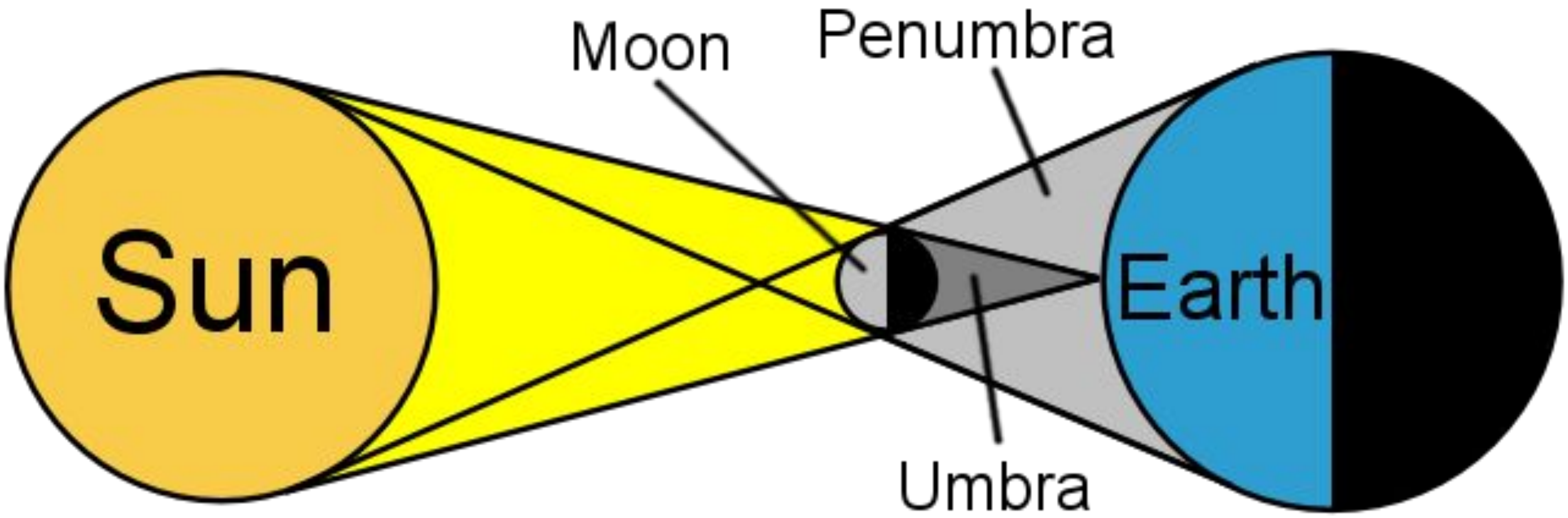

whenisthenexteclipse.com
SUN
EARTH
MOON
Umbra
Penumbra


PHOTOBOMB!
WHAT REALLY HAPPENS DURING A SOLAR ECLIPSE
UNEARTHEDCOMICS.COM 2016 ©SARA ZIMMERMAN








Sun
Moon
Penumbra
Earth
Umbra

Tab page front

Label: Planning and Carrying Out Investigations

TN Department of Education

Planning and Carrying Out Investigations

Tennessee Academic Standards for Science

Teacher Guide for Grade 5

Standard
5.PS2.1 Test the effects of balanced and unbalanced forces on the speed and direction of motion of objects.

Tennessee Academic Standards for Science: Page 42

Three-dimensional Learning Performance for Lesson
Students will plan and carry out investigations* in order to show the effects of balanced and unbalanced forces on the speed and direction of motion on objects ** highlighting the stability and change in a system.**

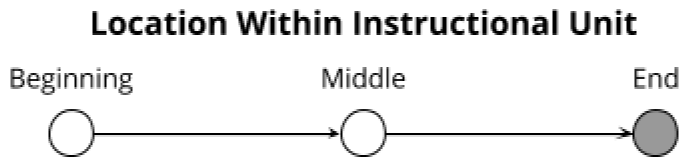
Science and Engineering Practice for Lesson
*Planning and carrying out investigations**
The goal of this three-dimensional learning performance is for students to plan and carry out an investigation that demonstrates balanced and unbalanced forces. It is important that the class has the time to explore how forces interact on different objects as they begin to plan their investigation.

Disciplinary Core Idea for Lesson
*Physical Science 2: Motion and Stability: Forces and Interactions***
"Interactions of an object with another object can be explained and predicted using the concept of forces, which can cause a change in the motion of one or both of the interacting objects. An individual forces acts on one particular object and is described by its strength and direction. The strengths of forces can be measured and their values compared. What happens when a force is applied to an object depends not only on that force but also on all the other forces acting on that object."

A Framework for K–12 Science Education: Page 114

Crosscutting Concept for Lesson
*Stability and Change****
Students will be able to describe that some systems are stable and that some systems are changing depending on the forces acting on them.

Prior Knowledge



- Concepts that should be covered before this lesson:
    - How to conduct a simple investigation
    - How to examine forces acting on objects, such as adding forces acting on an object and making a force diagram
    - Basics of balanced and unbalanced forces
        - Definition of the following: push, pull, balanced, and unbalanced forces
        - Newtons are the units of force

- This lesson covers all of standard 5.PS2.1

Materials

- Large block
- Small block
- Various size balls
- Spring scale
- Various size toy cars
- Poster boards (one for each group)
- Dominoes
- Index cards
- Popsicle sticks
- Marbles (small, large, weighted, plastic)
- Glue
- Tape
- Toilet paper/paper towel tubes
- Rubber band
- Cotton balls
- Straws
- Small cups
- Spoons

Lesson Sequence and Instructional Notes

Introduction

Use the terms balanced and unbalanced. Allow students to explain why they agree if it is balanced or unbalanced. This is from STEM teaching tools to get students to talk and discuss different situations.

Teacher:

1. Label or inform the students that one side of the room is the balanced and the other side of the room is the unbalanced side.
2. Have all the students make a line in the middle of the two identified sides.
3. Read a list of statements (listed below) that they will respond to.
4. Students will step out of the line and move toward the side that best describes the type of force represented in the statement.
5. Ask students follow-up questions to engage them in discussion with one another. Possible questions might include:
    - Why did you choose that side?
    - What would it take for you to change your mind?
    - What influenced your opinion?
    - Repeat with more statements.
6. After each statement, have students line back up and repeat the steps with a new statement.

Extension Opportunity - While students give their explanations for why they agree or disagree with a statement, the teacher may want to jot down these responses and visit them later after the station activity. This is an opportunity for students to review their initial thoughts and use evidence collected from the stations to revise their thinking and explanations or support their thinking and explanations to the statements.

What type of force? – Balanced or Unbalanced Statements – Explain

1. Act in opposite directions

Either balanced or unbalanced forces can act in opposite directions… Since all students will be correct, listen for the quality of their rationale. Students justifying balanced should justify based on the fact that an object at rest or with constant velocity will when the forces acting on the object are balanced. Students justifying unbalanced forces might contend that simply acting in opposing directions does not necessarily mean that the strengths of the forces are equal.

2. A book sitting on a table

Balanced is correct. Since the object is remaining at rest the forces acting on the object must cancel each other out.

3. Cause a truck to begin to move

Unbalanced forces do not cancel each other out, and will therefore cause an object to begin to move (accelerate).

4. A bicyclist moving with a constant speed.

Constant speed occurs when an object already in motion experiences balanced forces. In this case, the motion will be opposed by some form of rolling resistance. However, since the cyclist is not slowing down, there must also be a force exerted by the cyclist which exactly equals the resistive force, but does not exceed.

5. Two forces that are not equal in size

By definition, these are unbalanced. It is possible for two lesser forces to act in combination and equal a larger opposing force such that an object experiencing dissimilar individual forces still experiences a net zero force when all the dissimilar forces sum and cancel one another.

6. A parked car

Since the car is at rest, the forces acting on the car are said to be balanced. If parked on a level hill, the balanced set of forces would include gravity acting downward on the car with an upward, equal force exerted by the ground.

After reviewing students' current understanding of balanced and unbalanced forces, inform students that they will engage in a number of stations, where they will test how balanced and unbalanced forces affect different objects. For each station, the teacher needs to place the direction card in front of the materials.

Station #1 - Demonstrations

Demonstration Card Directions

- Block
  - Place the block on a flat surface.
    1. What forces are acting on the block? *Gravity and normal force*
    2. Are they balanced or unbalanced? Explain. *Balanced, similar system to the parked car example above.*

- Car
  - With your lab partner, push the car back and forth GENTLY between the two of you.
    1. What direction did the car go in? *The car went away from the pusher.*
    2. Explain why you think the car went on the path that it did. Use terms such as force, push, pull, balanced, and unbalanced. *The pusher exerted a horizontal force which was not balanced by the smaller friction force resisting the motion of the car.*
    3. Now, explain what makes the car stop. Would the car eventually stop on its own? How? *After the pusher is no longer in contact with the car, the only force acting on the car is the friction force. Since this force acts alone, the system of forces is unbalanced and the car slows.*

- Ball
  1. Place the ball on a flat surface.
  2. Is this an example of balanced or unbalanced force? Why? *See car or block rationales above.*
  3. GENTLY push the ball so that it goes across the surface.
  4. Draw the movement on your worksheet. *The motion can be shown by a series of arrows representing the motion of the car. Each successive arrow can be drawn shorter than the previous to convey that the car is slowing down.*
  5. Is this movement an example of balanced or unbalanced force? Why? *Unbalanced, see 3 above.*
  6. How would the system be changed if a sudden gust of wind happened in the room? Draw a diagram to support your answer. *Answers will vary, from slowing the ball to increasing its speed based on the direction of the strength and direction of the wind.*

- Dominoes
  1. Set up the dominoes in a row so that they will touch each other when they fall.
  2. How are you going to make the dominoes fall? *Exert an external force on the system.*
  3. Knock the dominoes over. Was this an example of an unbalanced or balanced force? What evidence do you have for your answer. *Since the*

dominos began to move when the outside force acted on the system, the forces acting on the system are considered unbalanced.

4. Draw your domino set-up in your journal and draw arrows to show the direction of movement.

Station #2 - Interpreting Diagrams

Students will classify each picture as balanced or unbalanced force. For the forces that are unbalanced, students will determine which way the object moves.

1. Balanced - No Movement
2. Unbalanced - Will move to the right
3. Unbalanced - Will move up
4. Unbalanced - Will move to the left

After all students have completed the two stations, go over the answers and then move to the independent investigation. Students will now take everything that they have learned to make and complete an investigation of their own.

Small Group Investigation of Balanced and Unbalanced Forces

Students will plan their own investigation using balanced and unbalanced forces to determine how forces act on small and large objects during the task.

- Students should plan out exactly what they will test before they begin. Students will complete one of the following design tasks.
    - Making a short roller coaster and testing the effects of different size and/or weight of the marbles
    - Making a launcher that shows the forces on different objects
- Teachers should have the following supplies available for student use: different marbles (weighted, plastic, normal, small, large sized), rubber bands, cups, popsicle sticks, glue, tape, cotton balls, ping pong balls, index cards, straws, spoons, small cups, etc.

This is an open inquiry activity that requires the students to come up with the investigation. The key is for students to come up with a simple investigation to describe balanced and unbalanced forces. If you are not comfortable allowing students to come up with their own investigation, you can give each group an assigned phenomena to investigate. Here are a few examples:

Sample student investigations

- Roller Coaster - weighted marble vs. non-weighted
- Launcher - cotton ball vs. ping pong ball

Have a class discussion and go through a sample investigation in front of the class. For example, we are going to build a product today to test balanced and unbalanced forces.

Sample Discussion Questions

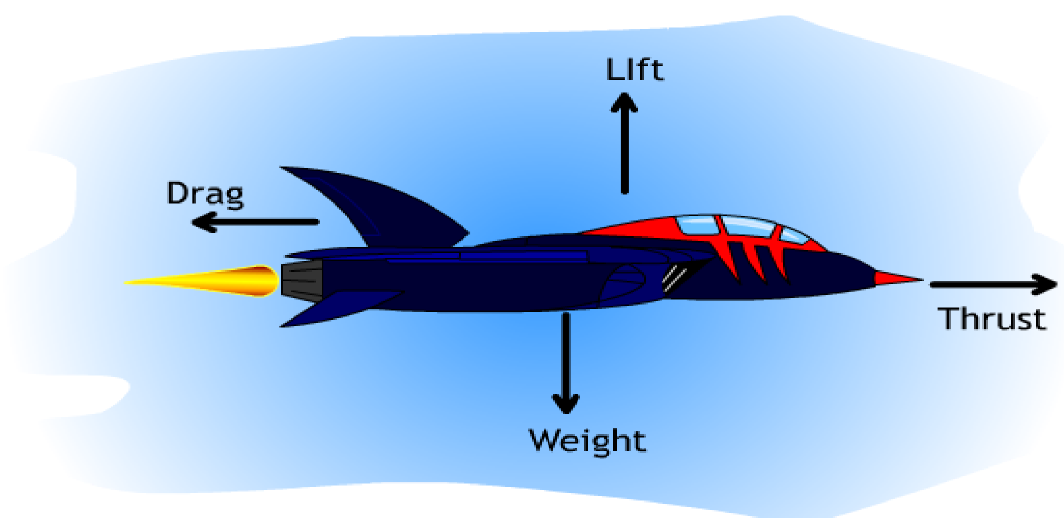
1. Do we want to make a marble run or a launcher?
2. What is one way to test how forces act on our product?
3. We only want to change one variable in our investigation. What will that variable be?
4. How should we collect our data?
5. How should we record our data?
6. You have to draw a free body diagram on our final poster. Let's model the forces on a flying jet. Model the forces on the board.
7. Any extra questions about designing, planning, and carrying out an investigation before we begin?

Directions on Free Body Diagram

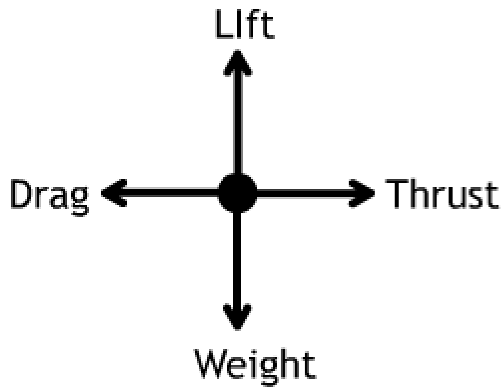
Free body diagrams are a tool for solving problems with multiple forces acting on a single body. The purpose of a free body diagram is to reduce the complexity of a situation for easy analysis. The diagram is used as a starting point to develop a mathematical model of the forces acting on an object.

In order to effectively use a free body diagram to analyze a body's motion in this lesson, we want students to be able to: 1. Identify the force acting on a body, 2. Identify the direction of each acting force and draw vectors representing the forces, and 3. Calculate the total amount of force on an object.

This diagram shows the forces acting on a flying jet.



But, instead of making students draw the actual object, students can draw a dot that represents the center of mass for the object, making the diagram easier to read and draw. An actual free body diagram of the jet, would look like the picture below.



Video Clip - Explaining the details on a free body diagram

Give students time to make a marble run or a launcher. Allow students time to plan their investigations. Have a small discussion with each group to ensure that they have an actual investigation planned.

When students are done with their investigation, students will make a poster presentation to display their work. They will present their investigation to another group. After presenting to one other group, you might ask select groups to present their findings to the entire class.

Student Directions to Work Through the Investigation

Pre-Investigation Questions

1. List all the things that affect the motion of an object.
   - Size of the object, friction, gravity, forces acting on it

2. What do you plan to do?
   - We plan to test the effects of a metal marble vs. a normal glass marble on our roller coaster design.

3. What are some factors that need to remain controlled?
   - Our device needs to remain steady the entire time.

4. What materials from the supply list do you plan to use?
   - We will use index cards and popsicle sticks to make our marble run. We will test with a normal marble and a weighted marble.

5. Make a prediction of what you think will happen in your investigation (hypothesis).
   - I think the normal marble will speed down our marble maze.

During the Investigation

- Create a table to collect and organize data.

Sample Tables:

Example #1

Trials (time down track)	Weighted Marble	Normal Marble
1		
2		
3		
Average Time it Took to Get to the Bottom		

Example #2

Trials - Distance Launched	Cotton Ball	Ping Pong Ball
1		
2		
3		
Average Distance		

After the Investigation - on your poster board

1. Write your hypothesis.
2. Make a list of materials that you used.
3. Explain your steps to complete it (Explain in details how someone else could repeat your investigation).
4. Draw a diagram to illustrate your investigation.
5. Draw a free body diagram of one of your objects in your device. Make sure diagram shows all forces acting on your object at three different points.
6. Make a data table that organizes your data.
7. Write one or two sentences summarizes your results.

Independent Assessment Question

Think about the game of bowling. Explain an example of balanced and unbalanced forces that could be observed during a game of bowling. Draw a freebody diagram showing multiple points during a frame of bowling. The diagram should explain at the different points whether it is a balanced or an unbalanced force.

Teacher Notes

For the stations, you could allow students to work through each station at their own pace, or you could time the each stations and then let everyone move on to the next.

Citations and Resources

https://www.myips.org/cms/lib8/IN01906626/Centricity/Domain/8123/Balanced%20and%20Unbalanced%20Forces%20Stations.pdf

http://www.morethanaworksheet.com/wp-content/uploads/2015/06/Balanced-and-Unbalanced-Forces-Investigation.pdf

Introduction

What type of force? – Balanced or Unbalanced - Explain

1. Act in opposite directions
2. A book sitting on a table
3. Cause a truck to move
4. Two forces that are not equal in size
5. A parked car

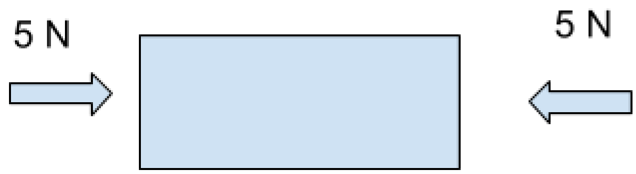
Stations

Station #1 - Manipulation Station

Demo	Illustration	Are the forces balanced or unbalanced? Describe the motion.
Block		
Car		
Ball		
Dominoes		

Create another two teams that are balanced.

Station #2 - Interpreting Diagrams
Please calculate the force acting on the box. Don't forget to include a direction.

1.


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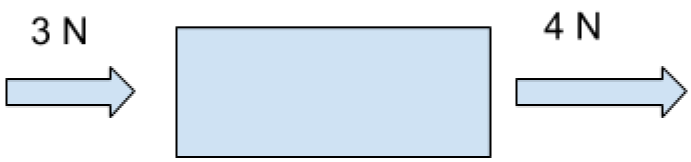

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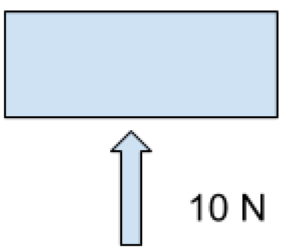

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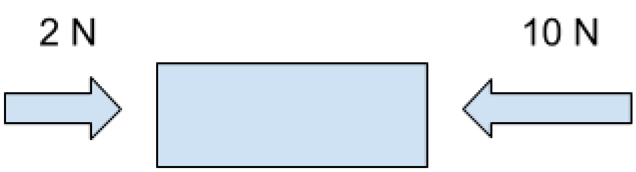


Small Group - Investigation of Balanced and Unbalanced Forces
You will plan your own investigation using balanced and unbalanced forces to determine how forces act on small and large objects.

You can pick from one of the design tasks to complete your investigation:

- Marble Run
- Launcher

You will present your investigation to a small group. After presenting to a small group, select groups will be asked to present their findings to the entire class. Please be sure to document your findings on a piece of poster board.

Supplies Available

- Index cards
- Popsicle sticks
- Marbles (small, large, weighted, plastic)
- Glue
- Tape
- Toilet paper/paper towel tubes
- Rubber band
- Cotton balls
- Straws
- Small cups
- Spoons

Pre- Investigation Questions

1. List all the things that affect the motion of an object.

2. What do you plan to do (procedures)?

3. What are some factors that need to remain constant or controlled?

4. What materials from the supply list do you plan to use?

5. Make a prediction of what you think will happen in your investigation (hypothesis).

During the Investigation

- Record everything that you are doing.
- Create a table to collect and organize data.

After the Investigation - on your poster board

1. Write your hypothesis.
2. Make a list of materials that you used.
3. Explain your steps to complete it (Explain in details so someone else could repeat your investigation).
4. Draw a diagram of figure to illustrate your investigation.
5. Make a Data table that organizes your data.
6. Write one or two sentences summarizes your results.

Independent Assessment Question

Think about the game of bowling. Explain an example of balanced and unbalanced forces that could be observed during a game of bowling. Draw a free body diagram showing multiple points during a frame of bowling. The diagram should explain at the different points whether it is a balanced or an unbalanced force.

Tab page front

Label: Constructing Explanations and Designing Solutions

TN Department of Education

Constructing Explanations and Designing Solutions

Tennessee Academic Standards for Science

Teacher Guide for Grade 5

Standard
5.ESS1.1 Explain that differences in apparent brightness of the sun compared to other stars are due to their relative distances from the Earth.

Tennessee Academic Standards for Science: Page 43

Three-dimensional Learning Performance for Lesson
Students will develop an explanation* in order to show that the brightness of the sun in comparison to other stars is due to relative distances from earth** highlighting the size and distance of our sun in relation to other stars.***

Science and Engineering Practice for Lesson
*Constructing Explanations**
Students will construct an explanation to answer the question: Why does the sun appear larger and brighter compared to other stars? The explanation will be based on evidence gathered through informational text, teacher demonstrations, and class discussion.

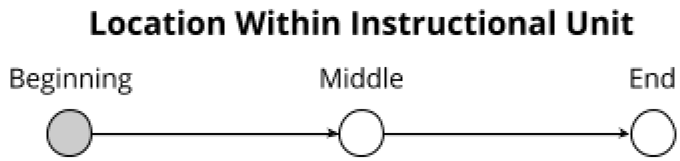
Disciplinary Core Idea for Lesson
*Earth's Place in the Universe***
Stars' radiation of visible light and other forms of energy can be measured and studied to develop explanations about the formation, age, and composition of the universe. Stars go through a sequence of developmental stages – they are formed; evolve in size, mass, and brightness; and eventually burn out. Material from earlier stars that exploded as supernovas is recycled to form younger stars and their planetary systems. The sun is a medium-sized star about halfway through its predicted life span of about 10 billion years.

A Framework for K–12 Science Education: Page 174

Crosscutting Concept for Lesson
*Scale, Proportion, and Quantity****
Stars have a wide range of apparent brightness measured here on Earth. The variation in their brightness is caused by both variations in their luminosity and variations in their distance. An intrinsically faint, nearby star can appear to be just as bright to us on Earth as an intrinsically luminous, distant star.[1]

[1] https://www.e-education.psu.edu/astro801/content/l4_p4.html

Prior Knowledge



- Concepts that should be covered before this lesson:
  - Earth's place within the solar system
  - Scale of solar system planet sizes and distance
- This lesson covers all of standard 5.ESS1.1:
  - Explain that differences in apparent brightness of the sun compared to other stars are due to their relative distances from the Earth.

Materials

- Student Activity Sheet
  - Star image from https://www.nasa.gov/pdf/145908main_Sun.As.A.Star.Guide.pdf (One printout/student)
- Post-It notes (3 X 3)
- Two flashlights of equal size with new batteries
- Video Clip: https://www.youtube.com/watch?v=HEheh1BH34Q
- Video Clip: https://www.youtube.com/watch?v=piuKlpJmjfg
- Stellarium Program - Teachers can download from this website: https://sourceforge.net/projects/stellarium/ (This is a free download.)

Lesson Sequence and Instructional Notes

Begin the lesson by asking students to complete the formative assessment probe titled "Is the sun a star?" on the student activity sheet. For added engagement, the teacher might show the following video clip as students are completing the assessment:

https://www.youtube.com/watch?v=piuKlpJmjfg

This is a short video clip showing the sun as it really is. The images were taken by NASA's Solar Dynamics Observatory. The audio is music only, which can be muted as the students work.

Have students share out their ideas from the formative assessment. The teacher might choose to poll the students to see how many agree with each of the students in the scenario given. Do not tell students if they are right or wrong at this point.

Tell students that they are going to read an informational text to gain further information about the sun. Students will turn to page 2 of the student activity guide. Point out to students that there are specific items that they should look for and annotate as they read:

- Underline the sentence that answers the question: Is our sun a star?
- Place a box around the sentence that provides the definition of a star.
- Circle the sentence that explains the size of our sun.
- Circle the sentence that describes the temperature of our sun.
- Underline the sentence that answers the question: How many stars are in our universe?

Teachers should read the text in a manner that is appropriate for their class.
Discuss each of the items above to clarify information about the sun and to establish that the sun is indeed a star.

- Underline the sentence that answers the question: Is our sun a star? *Unlike the ancient Greeks, we know that the sun is just a star.*
- Place a box around the sentence that provides the definition of a star. *A star is a huge, hot, bright ball of gas.*
- Circle the sentence that explains the size of our sun. *Our sun is a medium-sized star, somewhere between a giant and a dwarf.*
- Circle the sentence that describes the temperature of our sun. *Our sun, which appears yellow, has a temperature somewhere in between red and blue stars.*
- Underline the sentence that answers the question: How many stars are in our universe?
- *In fact, the sun is only one of billions of stars in the universe.*

Discuss each of the choices in the formative assessment above as a whole class discussion. The class should reach a consensus that Sam's answer is correct. Students should now work with a partner to rewrite each of the other statements into a correct statement. Alternately, teachers might choose to do this as a whole class, displaying the corrected statements for the class to complete as whole group.

Sam: "Our sun is just an average star made up of hot glowing gas. Correct.

Juanita: "Our sun is a huge ball of hot glowing gas~~, but it is too close to us to be a star."~~

Tillie: "Our sun is ~~one of the many~~ THE ONLY star found inside our solar system."

Skeeter: "Our sun ~~was once a planet but~~ is ~~now~~ a large burning ball."

Maggie: "Our sun is a star that is ~~bigger and hotter than any other star in our galaxy~~ MEDIUM-SIZED AND MEDIUM HOT."

Allison: "Our sun is a sun. It's not a star. Suns are different than stars."   Rewrite: Our sun is a star.

Now that students have a firm understanding that our sun is indeed a star, we can begin to compare our sun to other stars. The following video provides an interesting look at our sun's size in comparison to other stars. It is important to establish that stars vary in size before proceeding with the lesson. The video provides an opportunity for students to see that the sun is actually pretty small in comparison to most stars. However, later in the lesson, they will establish the fact that the sun, although smaller, appears much brighter because it is closer.

https://www.youtube.com/watch?v=HEheh1BH34Q

Remind the students that there are billions of stars in the universe. Our sun is the only star in our solar system, but when we look at the night sky, we can see the light from many stars that are outside of of solar system.

Tell the students that a website called Stellarium (http://stellarium.org/) was created to give us an idea of the characteristics of lots of different stars, including our sun.

Teachers will need to download the free Stellarium program before the lesson. Ask students to write down specific observations that they have about the stars in the sky, as you manipulate the website for them. A space has been provided on the student activity sheet for students to record their observations. The activity sheet provides some possible ideas for observations including color, temperature, size, etc.

Students should also write two questions about stars that are based on their observations. Students should record the questions on the student activity guide.

A. The following Youtube video provides easy instructions on how to use this simulation if needed: https://www.youtube.com/watch?v=bYF7SR99ZOw.
B. There are two toolbars. One is located on the bottom. The other is on the left side.
C. On the left toolbar, click on "Date/Time Window." A box will appear. Change the time until the screen appears dark and the stars are obvious.
D. Drag the screen around and point out different stars. You can click on a star and detailed information will be displayed. Most students will probably just be interested in the different names, colors, sizes, and brightness of the stars.
E. Go back to the "Date/Time Window." Continue to change the time until it is daylight again. By dragging the screen around, our sun comes into view. It appears very large and very bright in comparison to the stars that are visible at night.

Allow opportunity for students to share their observations with the class.

Ask students to share some of the questions that they have developed about the stars. The teacher should begin the process of guiding the class toward the development of a class question that has students research an explanation for the difference in the apparent brightness of stars. The following is one suggestion of how this might develop within the classroom:

Ask students to think back to the star comparison video. Remember that in the video, the sun was certainly not a very big star in comparison to the other stars in the universe. Ask students to think and then discuss why the sun looks so much brighter to us.

Ask: The sun is certainly not a very big star in comparison to other stars in the universe, but it looks so much brighter to us. Why?

Student responses will vary but will probably include:

- *The stars are different sizes.*
- *The stars are different temperatures.*
- *The stars are different distances away from us.*
- *Planets that reflect sunlight appear brighter than stars do.*

Ask: So, if we want to come up with <u>one</u> question about stars that will help us develop an explanation for our observations, what would that one question be? What question should we research today? Guide students toward the development of the following driving question:

- *Why do some stars appear brighter than others in the night sky?*

Students should record the class question on their activity sheet.

Tell the students that in order to answer the question, it is important to gather information about **<u>how</u>** star brightness varies and **<u>why</u>** star brightness varies.

A. Inform students that first we will look more closely at <u>how</u> the brightness of stars varies. Pass out a copy of the Star Image to each student. The Star Image can be found on page 37 of NASA's free resource titled "Sun as a Star." https://www.nasa.gov/pdf/145908main_Sun.As.A.Star.Guide.pdf
B. Have students turn to the Star Tally Chart in their student activity guide.
C. Explain to students that since there are so many stars in the picture, this is an opportunity to use a data technique that scientists use when an actual count would be very difficult.
D. Hand each student a post-it note square or other paper square approximately 3 X 3. Explain to the students that the square will be used to outline a sample area on the picture. The students will select a sample area, outline the square, and then count and classify only the stars in that sample area. Tell students that it is important to choose an area that is representative of the whole population – contains faint, medium, and very bright stars.
E. Students will determine for themselves how to classify each star's brightness. There will be some disagreement; however, there is enough difference of brightness in the photograph to provide for classification as a faint, medium, or very bright star.

F. Students will now count, tally, and graph their star brightness data. Students may mark each star as they count it to aid in obtaining a fairly accurate count.
G. Using the tally chart, students will create a bar graph. Some students may need support in deciding what intervals to use on the Y-axis of the graph.
H. As students finish, ask them to complete the next portion of the student activity guide: Using the data collected, how do the brightness of the stars compare in the star image presented? Take time to share out responses. *Students should note that there are many more faint stars than bright stars.*
   Ask: Why do you think so many more stars appear faint? *Student responses will vary, but at this point in the lesson students might suggest that fainter stars are farther away, cooler, etc.*

Tell students that now you want to do two demonstrations for them so that they can take a closer look at *why* brightness might vary. Ask students to go to Part VII on the student activity guide.

Demonstration #1:

A. Find two flashlights of the same size. Put new batteries in both flashlights so that the initial luminosity is the same.
B. Ask two students to hold the flashlights at an equal distance from a whiteboard or other wall so that the light can be easily observed.
C. Have students sketch a diagram at this point showing the two flashlights and resultant equal-sized bright circles of light.
D. Ask students for observations and conclusions about what they see. Students should observe that two stars (flashlights) of equal size have the same brightness when they are at the same distance.
E. Students should record this conclusion on their student activity chart. Note that the vocabulary term of “absolute magnitude” will be formally introduced at this time: When two stars are the same size, they have the same brightness. Scientists call this “absolute magnitude” or “actual brightness.”

Demonstration #2:

A. Using the same two flashlights, now have one student move much closer to the whiteboard.
B. Have students sketch a diagram at this point showing the two flashlights at different distances and the resultant UNEQUAL sized circles of light on the whiteboard.
C. Ask students for observations and conclusions about what they see. Students should observe that the closer the flashlight is to the whiteboard, the brighter and larger the light appears to be. The farther away the flashlight, the smaller and dimmer the light appears to be.
D. Students should record this conclusion on their student activity chart. Note that the vocabulary term of "apparent magnitude" will be formally introduced at this time: The closer a star is to Earth, the brighter it appears. Scientists call this "apparent magnitude" or "apparent brightness."

Teacher Background Information:

As you get closer to the wall, the light pattern thrown by your flashlight will become brighter and more concentrated. This is because the light has less distance over which to spread out. When you're further from the wall, the light from your flashlight continues to spread out until it hits the wall. Starlight behaves the same way.

Two different stars may give off the same amount of light, but will have different apparent brightness because they're different distances from Earth. The farther out a star is, the more its light will spread out, and less of that light will reach us. This results in a lower magnitude of brightness. If every star was the same distance away, they'd all appear as uniform little dots in the night sky.[2]

At this point of the lesson, teachers should be listening for an "Aha" moment with the students. The reason that the sun appears so much larger and brighter compared to other stars is simply because it is so much closer to the Earth.

Have students attempt an initial explanation to answer the question: Why do some stars appear brighter in the night sky? Students will complete this written response on the student activity sheet.

Differences in star brightness can be due both to the actual brightness of the star and how far away it is from us. The actual brightness depends on the size (the larger the star is, the brighter it tends to be) and temperature (hot stars are brighter, cooler ones are dimmer). However, how bright a star appears to be also depends on how far away from us it is. A dim star that is very close to us can appear to be brighter than a bright star further away. The sun, a medium-sized

[2] *http://demoscience.org/flashlight-star-science/*

star, is much, much closer to us than any other star in the sky, and consequently appears to be much, much brighter.

For further clarification, teachers may choose to show an appropriate video clip. The following is one age-appropriate example:

Crash Course: Glow On! https://www.youtube.com/watch?v=Zo-sKzMWYFA

Students will now complete the formative assessment on their student activity sheet. The assessment revisits the initial question and asks students to provide an explanation for the following:

- Explain how we know that our sun is a star. *Our sun is a star. We know this because it is a huge, hot, bright ball of gas that provides light and heat to the Earth.*
- Explain why our sun appears to be so much larger than other stars in the night sky. *Our sun appears to be larger than other stars in the sky because it is so much closer to the Earth. The sun is the only star in our solar system and it is the star that the planets revolve around. All the other stars that we see in the night sky are much farther away than our sun.*
- Explain why some stars appear brighter than others. *Stars can be different sizes. If a big star and a little star are the same distance away from the Earth, then the big star would look brighter.*
    - *Stars can also be different temperatures. A very hot star will be brighter than a cooler star.*
    - *Stars also can be different distances away from the Earth. If two stars are the same size, but one is much farther away from the Earth, then it will look fainter.*
    - *So, all three of these things combine to make some stars appear brighter than others in the sky.*
- Explain the difference between apparent brightness and absolute brightness. *Apparent brightness is how bright a star appears to us from Earth. Absolute brightness is how bright the star really is if we could line it up and compare it with other stars at an equal distance.*

Citations and Resources:

Lesson adapted from "Better Lesson Plans: Investigating Star Brightness and Distance"
https://betterlesson.com/lesson/635919/investigating-star-brightness-distance

https://www.youtube.com/watch?v=Zo-sKzMWYFA

https://www.youtube.com/watch?v=bYF7SR99ZOw

Formative assessment adapted from *Keeley, Page. (2012). Uncovering student ideas in astronomy 45 formative assessment probes. Arlington, Va. :National Science Teachers Association*

NASA: Sun as a Star
https://www.nasa.gov/pdf/145908main_Sun.As.A.Star.Guide.pdf

https://www.youtube.com/watch?v=HEheh1BH34Q

https://www.youtube.com/watch?v=piuKlpJmjfg

Informational Text Adapted from:
https://gtm-media.discoveryeducation.com/videos/DSC/data/DE_TheSunOurMostImportantStar_G6-8_WN_tk_WN_vp_SRM.pdf

Is the sun a star?

Part 1:
Six students were talking about the sun. They had several different ideas. Here is what they said:

Sam: “Our sun is just an average star made up of hot glowing gas.

Juanita: “Our sun is a huge ball of hot glowing gas, but it is too close to us to be a star.”

Tillie: “Our sun is one of the many stars found inside our solar system.”

Skeeter: “Our sun was once a planet but is now a large burning ball.”

Maggie: “Our sun is a star that is bigger and hotter than any other star in our galaxy.”

Allison: “Our sun is a sun. It’s not a star. Suns are different than stars.”

Which student do you agree with the most? _______________________

Explain why you agree.

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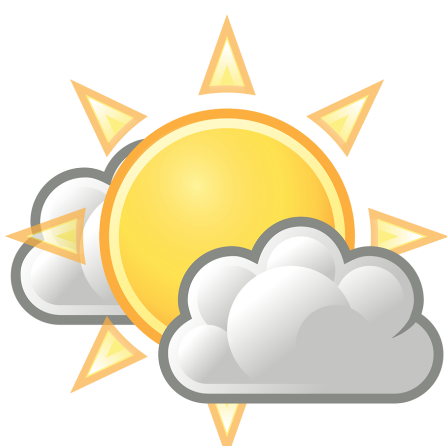


Part 2: Let's learn about the sun. Read the following informational text. As you read:

Underline the sentence that answers the question: Is our sun a star?
Place a box around the sentence that provides the definition of a star.
Circle the sentence that explains the size of our sun.
Circle the sentence that describes the temperature of our sun.
Underline the sentence that answers the question: How many stars are in our universe?

The ancient Greeks told many stories about Helios, the Greek god of the sun. Helios rose each morning at dawn from the ocean in the east. Helios then rode in his chariot, pulled by four horses through the sky. Helios finally rode each night into the ocean in the west.

Unlike the ancient Greeks, we know that the sun is just a star. In fact, the sun is only one of billions of stars in the universe. A star is a huge, hot, bright ball of gas. A star gives off both heat and light.

In the 1800s, scientists began to organize the stars into different categories. One way to organize the stars is based on their size. There are supergiant, giant, and dwarf stars. Our sun is a medium-sized star, somewhere between a giant and a dwarf.

Another way to organize stars is based on how hot they are. When you look at the stars, it may seem like they are all little white dots in the sky. But if you look closely you might notice that some look blue, yellow, or red. The color of stars has to do with their temperature. The hottest stars appear blue. The coolest stars appear red.

Our sun, which appears yellow, has a temperature somewhere in between red and blue stars. Our sun is one of millions in the sky. It is a perfect temperature to support life on Earth, and it provides us with sunny days and warmth. No wonder the Greeks were so amazed by it.

Retrieved from:
https://gtm-media.discoveryeducation.com/videos/DSC/data/DE_TheSunOurMostImportantStar_G6-8_WN_tk_WN_vp_SRM.pdf

Part 3: Use the information from the text and from class discussion to complete the table below. For each of the five student explanations that was incorrect, rewrite their response into one that you DO agree with.

Student	Modified Response

Part 4: Now let’s look at a cool simulation that will show us some of the billions of stars in our universe as well as our sun. It’s called “Stellarium.” As you view the simulation, work with your table group to complete the following:

Develop a list of at least four observations about the stars in the sky. You might include observations about color, size, brightness, temperature, etc.

1.

2.

3.

4.

5.

6.

Based on your observations, write two questions that you have about stars.

1.

2.

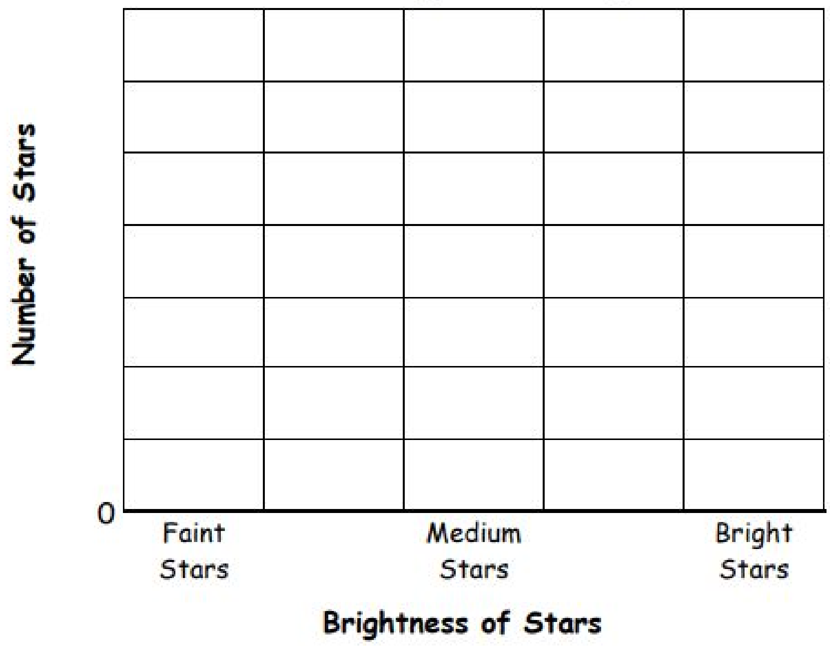
Part 5:

Focus Question:

Tally Chart

Brightness of Stars	Number of Stars
Faint	
Medium	
Bright	

Star Brightness Graph



Part 6: Using the data collected, how does the brightness of the stars compare in the star image presented?

Part 7: Now let's look at why the brightness of stars varies. Some stars look dim and some look bright to us from Earth. What effect does distance have on apparent brightness of a star?

Astronomers measure the brightness of stars in two ways: by how bright they appear from Earth and by how bright they actually are. Complete the following table as your teacher demonstrates.

	Diagram	Conclusion
EQUAL DISTANCE		

UNEQUAL DISTANCE		

Part 8: Let's put everything together to answer our science question! Using information from your models, the demonstration, and the data in your graph, explain why the brightness of stars vary in the night sky.

Why do some stars appear brighter than others in the night sky?

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Part 9: You are outside at night with Sam, Juanita, Tillie, Allison, Maggie, and Skeeter. Looking at all the stars in the night sky, they begin to argue again about whether the sun is a star, why it appears larger than other stars, and why some stars appear brighter than others. You tell them all to sit down and eat a s'more, and you will explain.

Using evidence from the above text, demonstrations, and class discussion, construct an explanation for your friends. Include the following in your explanation:

- ❖ Explain how we know that our sun is a star.
- ❖ Explain why our sun appears to be so much larger than other stars in the night sky.
- ❖ Explain why some stars appear brighter than others.
- ❖ Explain the difference between apparent brightness and absolute brightness.

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Citations and Resources:

Formative assessment adapted from *Keeley, Page. (2012). Uncovering student ideas in astronomy 45 formative assessment probes. Arlington, Va. :National Science Teachers Association*

Tab page front

Label: Engaging in Argument from Evidence

TN Department of Education

Engaging in Argument from Evidence

Tennessee Academic Standards for Science

Teacher Guide for Grade 5

Standard
5.LS4.1 Analyze and interpret data from fossils to describe types of organisms and their environments that existed long ago. Compare similarities and differences of those to living organisms and their environments. Recognize that most kinds of animals (and plants) that once lived on Earth are now extinct.

Tennessee Academic Standards for Science: Page 43

Three-dimensional Learning Performance for Lesson
Students will use evidence from fossils * in order to describe types of organisms and their environments that existed long ago** highlighting the similarities and differences of extinct organisms to living organisms and their environments.***

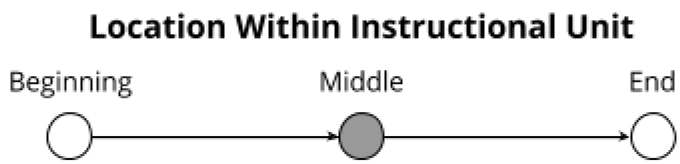
Science and Engineering Practice for Lesson
*Engage in Argument from Evidence**
Students will analyze and interpret data from fossils to use as evidence of environmental change over time.

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

A Framework for K–12 Science Education: Page 162

Crosscutting Concept for Lesson
*Structure and Function****
Students will examine fossils for structural features that can be used to infer the environment in which the organism lived. By comparing the features of extinct organisms to similar features of known organisms today, students begin to connect the role of structure and function with an organism's ability to survive in a specific environment.

Prior Knowledge



- Concepts that should be covered before this lesson:
    - Fossils are the preserved remains of once living organisms.
    - The fossil record represents a timeline of organisms that have lived on the Earth.
- This lesson covers portions of standard 5.LS4.1:
    - Analyze and interpret data from fossils to describe environments that existed long ago. Compare similarities and differences of those to living organisms and their environments.

Materials

- Student activity sheet
- Google Slide presentation (Included)
- https://www.youtube.com/watch?v=ZSt9tm3RoUU
- https://www.youtube.com/watch?v=V2EGuajQxXI

Lesson Sequence and Instructional Notes

Begin this lesson by telling students that you are going to show them a short video clip. This video clip does something pretty crazy – it's going to show the history of the Earth in one minute!

- Show one of the following Youtube video clips:
    - https://www.youtube.com/watch?v=ZSt9tm3RoUU
    - https://www.youtube.com/watch?v=V2EGuajQxXI

Ask students:

- How do we know that these events actually happened? *Students will probably suggest that eyewitnesses were able to record written history about many of the events.*
- How do we know about events that happened before people could write about them?
- How do we get evidence about the Earth's past? *The idea is to focus student attention on the fact that scientists must use evidence to understand the Earth's history. This evidence comes from studying the geologic processes of the Earth, including the fossil record, to piece together a "picture" of the Earth's past.*

Tell students that today they are going to be paleontologists. A paleontologist is a scientist who studies fossils and uses them as evidence to help understand what organisms that lived in the past looked like and how the Earth's environment has changed over time.

Part I of the Student Activity Guide

Show the first slide of the Google Slide presentation. Hand out the student activity sheet and begin with Part I. The first page of the student activity sheet guides students through an analysis of the fossil that is shown. Teachers may choose to read aloud and discuss each question as a whole class or have students complete the first page of the questions in small groups or pairs. However, it is important to have students share out their ideas to develop a consensus regarding the structural characteristics that can be used as comparison.

- **Possible Student Responses To Student Activity Questions**
  - What animal(s) that lives today does this fossil most resemble? *Alligator or crocodile*
  - What specific features about the fossil helped you to reach your decision? *Answers will vary but students will probably refer to the general shape of the animal including the long tail, triangular shape of the head, sharp teeth, short limbs.*
  - Describe the type of environment in which this animal most likely lived. *Since crocodiles and alligators of today live near water, most students will probably suggest that this organism also lived near some type of water: ponds, lakes, etc.*
  - What evidence supports the idea that the animal may have lived in the environment that you described above? *The goal is for students to do exactly what scientists actually do – compare the fossil to modern-day animals and then infer that similar traits and characteristics were there for the same purpose that they are used by animals today.*
  - What types of food did this animal most likely eat? *The sharp teeth will probably suggest that this animal ate other animals.*

Go to slide two of the presentation. Students should go to page 2 of the activity sheet. The pictures show the location in the Sahara Desert where this fossil was found. The fossil is referred to as "Super Croc," and this particular fossil was found in 1997 by a team of scientists sponsored by National Geographic.

- Ask students:
  - How could this organism have existed in this environment? *Some students may suggest that the organism must not have needed water in the same way that modern crocodiles do. However, remind students that this organism lived millions of years ago!*

- Could the place where this fossil was found have been different millions of years ago? *In fact, this desert region was once a humid, tropical environment containing fresh water.*

Show students slide three of the presentation. This slide provides an idea of the actual size of this organism. Included on this slide is a link to a website: 10 Facts About Sarcosuchus, the World's Biggest Crocodile. As students view the 10 facts, use this opportunity to point out those features of the organism that are different when compared to crocodiles of today. For example, their eyes rolled up to down instead of left to right. The body was completely covered in "armored plates" as opposed to modern crocodiles that have a "break" in the armored plates on their body. The Sarcosuchus was estimated to weigh as much as 10 tons.

Part II of the Student Activity Guide

Read aloud the introductory paragraph on this page. Focus on the fact that fossils can be used as evidence to show what organisms looked like in the past as well as what the past environment was like.

Tell students that they are now going to examine pictures of three more fossils and see if they can figure out in what environment each of them lived. They will have to use the fossils as evidence to support their conclusions.

Have students work in pairs or small groups to complete the next three examples on the activity sheet.

The Google Slide presentation is designed to correspond with the student activity sheet.

Show the fossil of the Shonisaurus popularis. Have students share their reasonings as to the environment that existed at the time this fossil lived.

- What specific physical/structural features do you notice?
  - *Limbs that appear to resemble flippers, large body shape, head with a "beak" type snout or nose*
  - *Appears to resemble a turtle or large fish*
- What modern-day organisms do you think might be related to this organism?
  - *Perhaps a sea turtle, large fish, or even a whale*
- What inferences can be made about its ancient environment?
  - *This animal would have needed an aquatic or marine environment with lots of water to swim in.*

After students have shared their responses, go to the next slide, which shows information about where the fossil was actually found and what scientists think the organism may have actually looked like. The idea is to reinforce that this fossil shows that Nevada must once

have been covered in water and indeed was actually a deep ocean millions of years ago. The fossil is used as evidence to show the past environment.
Repeat this process with the next example of the Aepycamelus giraffinus.

- What specific physical/structural features do you notice?
    - *A long neck, four legs, tail, a relatively small head*
- What modern-day organisms do you think might be related to this organism?
    - *Most students should suggest a giraffe with a long neck*
    - *It also resembles a camel in general body structure as well*
- What inferences can be made about its ancient environment?
    - *Since it resembles a giraffe with its long neck, it probably lived in an area with trees or tall shrubs that required the long neck to reach its food source*

After students have shared their responses, go to the next slide, which shows information about where the fossil was actually found and what scientists think the organism may have actually looked like. This fossil has been found in Montana, California, and even Florida. The appearance of the organism provides evidence of the type of past environment.

Repeat the process with the next example of the Gastornis (Flightless Bird) and a species of Fern.

- What specific physical/structural features do you notice about EACH?
    - Animal Fossil:
        - *It is obviously a large bird of some type. It appears to have a long neck and long legs as well.*
    - Plant Fossil:
        - *It is the leaf from a plant of some sort. It appears to have several small leaflets coming from a central stem.*
- What modern-day organisms do you think might be related to EACH organism?
    - Animal Fossil: *It is obviously a bird. Some students may suggest that it resembles an ostrich or an emu.*
    - Plant Fossil: *Answers will vary, but many students will probably recognize that this is a fern.*
- What inferences can be made about their ancient environment?
    - *Students may have varying answers here and that is fine. The impact is made with the next slide, which shows that these fossils were both found in what is now modern-day Arctic territory. Both of these organisms would have needed a warm, more tropical environment in order to survive. These fossils provide evidence that the arctic area of today had a very different environment millions of years ago.*

Part III of the Student Activity Guide

Show students the last slide with the state fossil of Tennessee. Students will now complete a short Claim-Evidence-Reasoning response to show understanding of how fossils can be used to provide evidence of past environments.

Sample Response:

- Claim: Millions of years ago, land in West Tennessee must have been covered in water or an ocean.
- Evidence: The fossil looks like a shell that comes from something that lives in the ocean. It has the same appearance as many seashells that we see today.
- Reasoning: Seashells come from oysters, clams, and other animals that live in the water. Many of them live in the ocean. SInce many of these fossils have been found in West Tennessee, that shows that the land must have been an ocean millions of years ago.

Background Information for Teacher[1]

Pterotrigonia (Scabrotrigonia) thoracica is the official state fossil, as designated by House Joint Resolution 552 of the 100th General Assembly in 1998. Tennessee was the thirty-eighth state to designate a state fossil.

Pterotrigonia (Scabrotrigonia) thoracica (nicknamed Ptero) was a Cretaceous bivalve found in the Coon Creek Formation of West Tennessee. It was a wedge-shaped, shallow-burrowing suspension feeder that inhabited the marine clayey-sand ocean floor that was West Tennessee seventy million years ago. Shells of Ptero are preserved unaltered in great abundance and are easily recognized by collectors. The associated ocean floor inhabitants were diverse and included other bivalves, snails, squid-like animals, worms, sponges, corals, crustaceans, sharks, fish, turtles, and marine reptiles. Ptero is now extinct. In fact, the extinction event that was responsible for the demise of the dinosaurs sixty-five million years ago may have contributed to the demise of Ptero. Only the genus *Neotrigonia*, with five species, has survived to the present and is found only in the Pacific Ocean, most commonly near New Zealand.

Citations and Resources

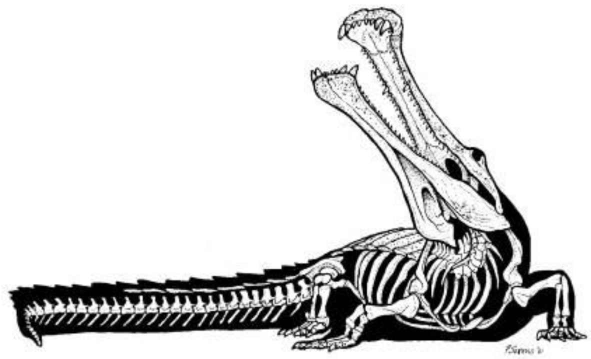
https://www.youtube.com/watch?v=ZSt9tm3RoUU
https://www.youtube.com/watch?v=V2EGuajQxXI
http://www.prehistoric-wildlife.com/images/species/s/sarcosuchus-size.jpg
http://oceansofkansas.com/Ichthyosaur/ich-skel.jpg
https://www.thoughtco.com/facts-about-sarcosuchus-worlds-biggest-crocodile-1093333
http://www.prehistoric-wildlife.com/species/s/shonisaurus.html

[1] https://sos.tn.gov/products/state-fossil

http://www.planet-franken-online.de/ries/aepycamelus.jpg

Digging Up the Past

Part I: The fossil shown below was found in 1997. Paleontologists estimate that this animal lived approximately 110 million years ago.



What animal(s) that lives today does this fossil most resemble? ___________________________

____

What specific features about the fossil helped you to reach your decision?

____

____

Describe the type of environment in which this animal most likely lived.

____

What evidence supports the idea that the animal may have lived in the environment that you described above?

____

____

What types of food did this animal most likely eat? ______________________________________

____

The pictures below show the location and environment of the fossils when they were discovered.

itouchmap.com

Explain how the organism shown above could have existed in this environment.

____

____

____

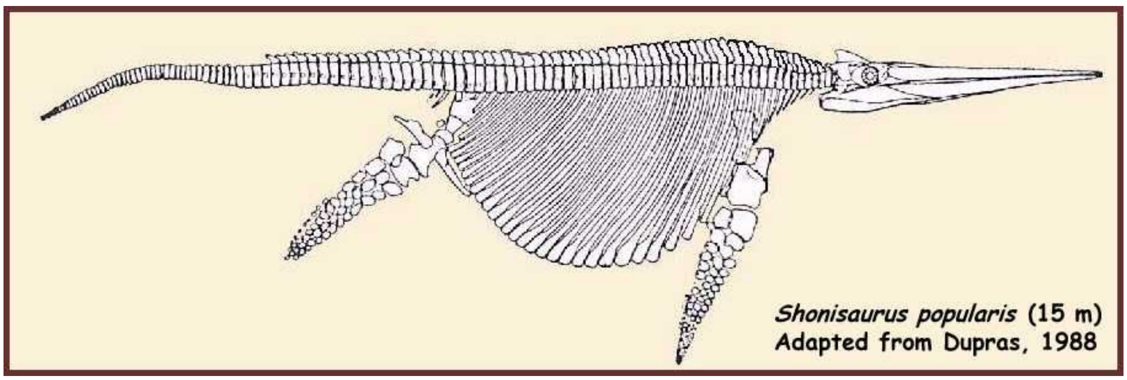
____

Part II: How can we use fossils to predict what a past environment was like?

The climate in an environment is one of the factors that determines where different species of plants and animals can live. Paleontologists look for clues to a location's ancient climate in the types of fossil plants and animals they find there.

The fossil above is from an extinct animal called the *Sarcosuchus Imperator* and is related to our modern crocodiles of today. Modern crocodiles live in areas where it is warm year-round. They are semi-aquatic and live near lakes, rivers, and large ponds. So, scientists infer that at one time, the desert environment where this fossil was found must have been a lush, tropical environment with plenty of freshwater for this "Super Croc" to live in. The teeth of the Super Croc are thinner than its modern-day ancestors, so most scientists think that its diet consisted mainly of fish and other small aquatic animals.

Examine each of the fossils below. Compare them to modern-day organisms to help determine the ancient environment in which the organism may have lived.

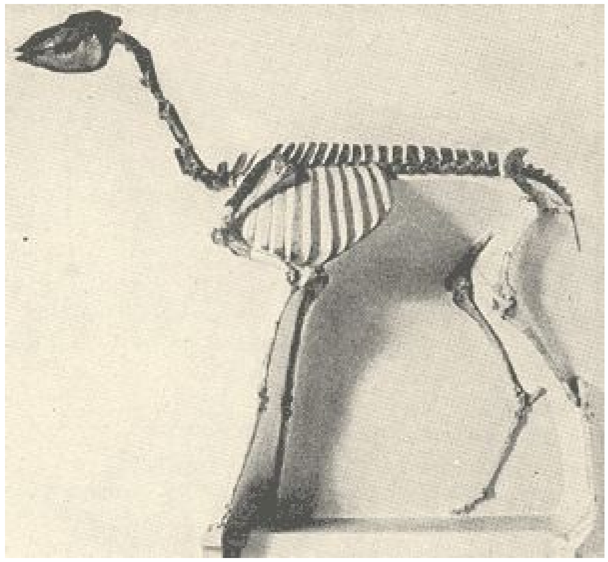


This organism lived approximately 215 million years ago.

1. What specific physical/structural features do you notice?

2. What modern-day organisms do you think might be related to this organism?

3. What inferences can be made about its ancient environment?



This organism lived 15 million years ago.

1. What specific physical/structural features do you notice?

2. What modern-day organisms do you think might be related to this organism?

3. What inferences can be made about its ancient environment?


These two organisms lived around 50 million years ago in the same geographic area.

1. What specific physical/structural features do you notice about EACH?

Animal Fossil:

Plant Fossil:

2. What modern-day organisms do you think might be related to EACH organism?

Animal Fossil:

Plant Fossil:

3. What inferences can be made about their ancient environment?

Part III: The fossil shown below is the official state fossil of Tennessee. Many of these fossils have been found in West Tennessee.

This organism lived about 70 million years ago.

Complete a short response using the Claim-Evidence-Reasoning format to explain how this fossil can be used to determine what type of environment existed in Tennessee in the past.

Claim:

Evidence:

Reasoning:

Tab page front

Label: Asking Questions and Defining Problems

TN Department of Education

Asking Questions and Defining Problems

Tennessee Academic Standards for Science

Teacher Guide for Grade 5

Standard
5.ESS1.3 Use data to categorize different bodies in our solar system including moons, asteroids, comets, and meteoroids according to their physical properties and motion.

Tennessee Academic Standards for Science: Page 43

Three-dimensional Learning Performance for Lesson
Students will generate scientific questions based on data[*] in order to show that data can be used to classify the bodies in our solar system [**] highlighting the different bodies that make up our solar system.[***]

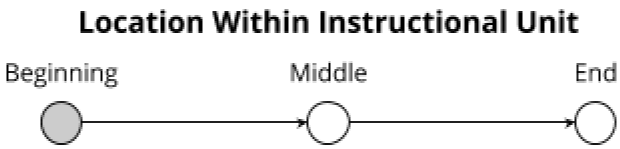
Science and Engineering Practice for Lesson
Ask and Develop Scientific Questions[*]
In this activity, students will have opportunity to develop questions which will serve as the basis for the data that the students will collect in order to classify the bodies in our solar system. Teachers will guide students toward developing "priority" questions based on the use of the "Question Formulation Technique."

Disciplinary Core Idea for Lesson
Earth's Place in the Universe[**]
The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids, that are held in orbit around the sun by its gravitational pull on them. In addition, the Tennessee Academic Standards for Science also include comets and meteoroids in the list of objects to be categorized.

A Framework for K–12 Science Education: Page 176

Crosscutting Concept for Lesson
Systems and System Models[***]
This activity is designed to develop understanding of the basic components of the solar system and the current rationale for classification of each. This lesson serves as a foundation for future learning in which students will develop a model of the solar system in order to understand the interactions of the components.

Prior Knowledge



- Concepts that should be covered before this lesson:
    - Use data to categorize the planets in the solar system as inner or outer planets according to their physical properties
    - Scale of solar system planet sizes and distance
    - The sun is the only star in our solar system and the major planets revolve around the sun through a combination of gravity and inertia.
- This lesson covers portions of standard 5.ESS1.3. The lesson can serve as an introduction to the standard, although teachers will want to develop additional learning opportunities for students to provide greater depth of understanding of each component.
    - Use data to categorize different bodies in our solar system including moons, asteroids, comets, and meteoroids according to their physical properties and motion.
- Pairing this content with a number of standards under 5.PS2 will strengthen a student's understanding of both core ideas and relevant crosscutting concepts.

Materials

- Question Formulation Technique (Developed by rightquestion.org)
    - http://www.ibmidatlantic.org/Experiencing-the-QFT.pdf
- Informational text article:
    - https://www.cnn.com/2017/11/20/world/first-interstellar-object-solar-system/index.html
- Solar system images for student card set:
    - https://www.calacademy.org/educators/lesson-plans/sorting-the-solar-system
    - https://astrosociety.org/edu/publications/tnl/70/solarsystemcards.pdf
- Information Resource Suggestions for Students:
    - Comets, Meteors, and Asteroids:
        - http://www.daviddarling.info/childrens_encyclopedia/comets_contents.html
        - https://newsela.com/read/lib-nasa-comets/id/21968
        - https://newsela.com/read/lib-nasa-meteors-meteorites/id/21973/
        - https://newsela.com/read/lib-nasa-asteroids/id/22460/
        - http://curious.astro.cornell.edu/our-solar-system/comets-meteors-and-asteroids

        - https://spaceplace.nasa.gov/asteroid-or-meteor/en/
        - https://www.youtube.com/watch?v=dvd47rMYia0
    - Dwarf Planets:
        - https://newsela.com/read/elem-sci-space-pluto/id/33839/
        - https://www.space.com/15216-dwarf-planets-facts-solar-system-sdcmp.html
        - https://www.youtube.com/watch?list=PL9TFrgFq7555w3vnggH2h32dUuGysJFvb&v=fIp4Ay1_-mI
        - https://www.youtube.com/watch?v=8x06kN4ZMOE
    - Moons:
        - https://www.universetoday.com/60072/what-is-a-moon/
        - https://www.thoughtco.com/what-is-a-moon-3073438
        - https://www.youtube.com/watch?v=tYYgHq1FfDk

Lesson Sequence and Instructional Notes

Begin the lesson by focusing student attention on the title of the student activity sheet: *How do scientists classify objects in our solar system?* Tell students that today they will be deciding which questions they need to ask so they can obtain the information they need to categorize the various objects in our solar system. Although they may have lots of great questions about the solar system, we need to use the questions that will help us get the right information.

Read the introductory informational text in the manner appropriate for your class. The article ends with a question, "What is it?" Tell the students that even scientists were confused when they first saw this object through their telescopes and couldn't decide exactly what it was.

Teacher Background Information: The object is actually an interstellar object named "Oumuamua." Initially, scientists classified the object as a comet, but then decided it was an asteroid. Realizing that the object actually originated from outside of our solar system, the International Astronomical Union developed a new category: I for "Interstellar" Oumuamua is officially classified as I1. Its origin and age are unknown.

Ask students to complete the question that follows the text on the student activity sheet. These questions can serve as a simple formative assessment to see current student understandings and misconceptions:

What types of objects are in our solar system? List as many objects as you can think of in the space below. Circle the category that you think the pictured object above would most likely belong to.

- *Planets - 8*

- *Asteroids*
- *Moons*
- *Dwarf Planets - 5 officially recognized*
- *Meteoroid*
- *Comets*
- *Sun - a star*
- *Students may think the pictured object most resembles an asteroid, comet, meteoroid, or even small moon.*

The purpose of the activity is to unpack what students already know and to note any misconceptions that can be addressed at a later point in the lesson. Do not correct students at this time, but only listen for their ideas of the components in the solar system.

Students might mistakenly say that there are multiple stars in our solar system, although there is only one star, our sun. Some students may mistakenly say that there is only one moon in the solar system, even though there are several moons that orbit around other planets. Other answers may include artificial satellites such as space probes.

Inform students that they are now going to do an activity to see how well they can classify some objects in our solar system. It is okay if they are not sure of the answers! This activity is called "Solar System Classification Sort.".

- Prior to the lesson, make a set of cards for each group of students to use. Teachers will want to choose around 25-30 images to make up each set. Images can be found at the following two sites:
  - https://www.lpi.usra.edu/education/orexlaunch/SortingSolarSystem.pdf
  - https://astrosociety.org/edu/publications/tnl/70/solarsystemcards.pdf
- Take out the image card of Ceres from each set of cards BEFORE handing the cards to students.
- Detailed directions (including a teacher script) for the activity can be found at this site:
  - https://www.lpi.usra.edu/education/orexlaunch/SortingSolarSystem.pdf
- Simplified Directions for the activity (from California Academy of Sciences):
  - Break the class into small groups and give each group a set of cards.
  - Explain that scientists sort things by their characteristics – size, composition, and position are examples of how things can be categorized.
  - Ask each group to work together as scientists to sort the objects into categories based on their characteristics. It's up to them to determine what categories to create.
  - When the groups have completed sorting the objects, select one card and ask each group to describe how they categorized it. What characteristics does it share with the others in that category? Could the object fit into more than one category they have created?
  - Different groups might categorize the same object differently. Discuss the differences between the group's categories.

  - Explain how scientists carefully observe new discoveries and apply their knowledge of existing objects to help understand and describe what they have found.
  - Now, hand each group of students a Ceres card. Ask: How would you classify this object based on your categories? Would anything have to change?
  - Collect the card sets. It is not essential at this point to provide the correct answers to the students as far as how the cards should be grouped. The idea is to have students begin to think in terms of what characteristics are used to help scientists classify these object.

Transition students to the next activity by explaining to them that scientists also have to make decisions about how to classify the components of our solar system. By asking the right questions, the students can obtain the information that they need to learn about the different objects in our solar system and how they are classified.

Teachers will now guide students in the development of questions that will lead to an understanding of how scientists classify these objects. The goal is for the students to develop specific questions regarding the physical properties of these components, such as:

- What is it made of?
- What is its orbit like?
- What shape is it?
- How big is it?

It can be difficult to support students as they develop questions without just providing the answers. A strategy that teachers might find helpful to use in guiding students toward developing questions is called the "Question Formulation Technique.". The directions for this procedure can be found here: http://www.ibmidatlantic.org/Experiencing-the-QFT.pdf.

For teachers not familiar with the "Question Formulation Technique," it is suggested that only a simplified version be used with students. A suggested format is shown below:

- Teachers should start by showing the following Focus Statement to the students. For this lesson, the focus is: Within our solar system there are different bodies such as planets, dwarfs planets, moons, comets, asteroids, and meteoroids.
- Tell students to think silently for a few moments about the statement.
- Tell students to look at the "Asking Questions Guidelines" on their student activity sheet. Go over each guideline with the class. Here are the guidelines that they will use when developing the questions:
  - Ask as many questions as you can.
  - Do not stop to discuss, judge, or answer any questions.
  - Write questions exactly as they are stated.
  - Change any statements to questions.

Ask students to work with their table group to brainstorm as many questions as they can based on the focus statement. Students will work in groups to ask as many questions as they can about the bodies in the solar system.

Teachers may find it helpful to set a timer for 10-15 minutes to allow enough time for students to brainstorm and record their list of questions on the student activity sheet.

At the end of the brainstorming session, tell students that they are going to focus on categorizing all these bodies in the solar system based on physical properties, just as they did in the card sort activity.

- Ask students, "How can we categorize all these bodies in the solar system by their physical properties?
- Ask students to look at the questions on their group chart and identify *three* questions that they think would support them in answering this question. These are referred to as their "priority questions". Allow time for students to record their priority questions on the student activity sheet as well as their rationale. *Students may ask questions such as, "Has an asteroid ever hit the Earth?" or "Has an astronaut ever walked on an asteroid?". Acknowledge that these are interesting questions but that they don't help us with our goal of learning how to classify the different bodies based on physical characteristics.*

Engage students in a whole class discussion so that groups can share out their priority questions. Alternately, teachers might want students to write the questions on poster paper so that students can do a "gallery walk" to see the questions that have been developed.

Teachers will need to guide students toward those questions which will help to obtain the necessary information.

- *What are comets, asteroids, and meteors made of? (Composition)*
- *How large does something have to be in order to be a planet? (Size)*
- *What is the difference in how these objects move? (Orbits)*
- *Where do comets come from? (Origin)*
- *Where do asteroids come from? (Origin)*
- *Where do meteoroids come from? (Origin)*
- *What are the different shapes of the bodies? (Shape)*

For example, teachers could write the priority questions of each group so that the entire class can see them. (Some of the questions will repeat and don't need to be written multiple times.) Ask the class to vote on which four questions they would like to research first. Put a star beside of those questions and have the students write those questions at the top of the table on the student activity sheet.

After class discussion, help the students to reach consensus about which questions they want to research in order to learn about the physical properties of the different small solar system bodies. Students will write the questions on the table on the student activity sheet.

Example:

Type of Body	**What is it made of?**	**What shape is it?**	**How does it move (orbit)?**	**How big is it?**
Planet				
Dwarf Planet				
Asteroid				
Moon				
Comet				
Meteoroid				

Students should be given access to resources to obtain the answers to their questions. Teachers can assign the research in a variety of ways, depending on the needs of the students.

- Each group member could research one question. For example, one student in a group would research the composition of planets, moons, asteroids, meteoroids, etc. Another student could research the size of each, etc.
- Each member of a group could be assigned one or two of the bodies to research. For example, one student could research asteroids. A different student could research planets and dwarf planets, etc.
- Each group in the classroom could research only one body. For example, all the members of a group could become experts on dwarf planets. Another group could research only asteroids.

Point out to students that extra space is provided on the student activity sheet to record any other information that they think is important to know so that the bodies can be classified.

A list of suggested resources for students is included in the materials section. Informational text can be printed as needed. Teachers should provide research time as appropriate for their students.

It is important to bring the class back together to share their findings. Focus students back to the original question: How do scientists classify objects in our solar system?

Do they have enough information to answer this question? Is there other information that is needed? What else do they need to know? The following provides background information to the teacher about each object:

The International Astronomical Union defines a planet as being in orbit around the sun, has enough gravity to pull its mass into a rounded shape), and has cleared its orbit of other, smaller objects. This last criterion is the point at which planets and dwarf planets differ. A planet's gravity either attracts or pushes away the smaller bodies that would otherwise intersect its orbit; the gravity of a dwarf planet is not sufficient to make this happen.

A moon is defined to be a celestial body that makes an orbit around a planet.

Asteroids orbit our sun, a star, in a region of space between the orbits of Mars and Jupiter known as the Asteroid Belt. Asteroids are solid, rocky and irregular bodies. Most asteroids are irregularly shaped, though a few are nearly spherical, and they are often pitted or cratered.

Comets are cosmic snowballs of frozen gases, rock and dust roughly the size of a small town. When a comet's orbit brings it close to the sun, it heats up and spews dust and gases into a giant glowing head larger than most planets. The dust and gases form a tail that stretches away from the sun for millions of kilometer. Comets orbit the sun. Some comets orbit the sun in a relatively short period of time. Others may take thousands of years.

Meteoroids are small pieces of rock and metal floating in space. Meteors are meteoroids that enter the Earth's atmosphere and usually burn up. When they enter the atmosphere, friction with air particles causes them to burn creating a bright streak in the night sky. They are often referred to as "shooting stars". Meteorites are the debris left over if a meteor makes it all the way through the atmosphere and impacts the Earth.

The following is an example of a formative assessment that could be given to assess student understanding of the basic components of the solar system and the characteristics currently used to classify each:
http://www.weaverusd.k12.ca.us/files/user/452/file/worksheet_smallbodies.pdf

Two additional questions are provided for lesson closure:

1. Based on the information that you have gathered, how would YOU classify the object in the picture at the beginning of the lesson? Explain your reasoning.

- *Although it came from outside our solar system and is just "traveling through," it most resembles an asteroid (although it did not originate in our own asteroid belt). It has an irregular appearance and appears to be made of rock.*

2. Recently, some scientists have decided that there should be yet another new definition for a planet. New Definition: Round objects in space that are smaller than stars. How would this change our current classification system?

    - *This would make all Dwarf Planets and even moons reclassified as "planets.".*

Citations and Resources

http://www.weaverusd.k12.ca.us/files/user/452/file/worksheet_smallbodies.pdf
http://www.ibmidatlantic.org/Experiencing-the-QFT.pdf
https://www.cnn.com/2017/11/20/world/first-interstellar-object-solar-system/index.html

Solar System Images for Student Card Set:
https://www.calacademy.org/educators/lesson-plans/sorting-the-solar-system
https://astrosociety.org/edu/publications/tnl/70/solarsystemcards.pdf

Comets, Meteors, and Asteroids:
http://www.daviddarling.info/childrens_encyclopedia/comets_contents.html
https://newsela.com/read/lib-nasa-comets/id/21968
https://newsela.com/read/lib-nasa-meteors-meteorites/id/21973/
https://newsela.com/read/lib-nasa-asteroids/id/22460/
http://curious.astro.cornell.edu/our-solar-system/comets-meteors-and-asteroids
https://spaceplace.nasa.gov/asteroid-or-meteor/en/
https://www.youtube.com/watch?v=dvd47rMYia0

Dwarf Planets:
https://newsela.com/read/elem-sci-space-pluto/id/33839/
https://www.space.com/15216-dwarf-planets-facts-solar-system-sdcmp.html
https://www.youtube.com/watch?list=PL9TFrgFq7555w3vnggH2h32dUuGysJFvb&v=fIp4Ay1_-mI
https://www.youtube.com/watch?v=8x06kN4ZMOE

Moons:
https://www.universetoday.com/60072/what-is-a-moon/
https://www.thoughtco.com/what-is-a-moon-3073438
https://www.youtube.com/watch?v=tYYgHq1FfDk
https://www.lpi.usra.edu/education/orexlaunch/SortingSolarSystem.pdf
https://astrosociety.org/edu/publications/tnl/70/solarsystemcards.pdf
https://www.lpi.usra.edu/education/orexlaunch/SortingSolarSystem.pdf

On October 19, 2017, the Pan-STARRS 1 telescope in Hawaii spotted something strange zooming through our solar system. It turned out to be a visitor from beyond our solar system, and it's unlike anything astronomers have seen before.

At first, astronomers thought the rapidly moving faint light was a comet or an asteroid that had originated in our solar system. But based on its orbit, the astronomers realized that the object came from interstellar space

"What we found was a rapidly rotating object, at least the size of a football field, that changed in brightness quite dramatically," said lead study author Karen Meech, of the University of Hawaii's Institute of Astronomy and leader of the research team, in a statement.

The long and rocky cigar-shaped object has a burnt dark-reddish hue due to millions of years of radiation from cosmic rays. This hue is similar to that of objects found in the Kuiper Belt, in the outer part of our solar system, but its orbit and shape firmly place it in the category of interstellar origin. It most likely has a high metal content and spins on its own axis every 7.3 hours.

But the shape, 10 times as long as it is wide, has never been seen before. This complex and convoluted shape means the object varies incredibly in brightness. So, what is it?

1. What types of objects are in our solar system? List as many objects as you can think of in the space below. Then, circle the type of object in your list that you think most likely identifies the object in the picture above.

2. Solar System Classification Sort - Work with your partner to sort the objects into categories based on some common characteristics.

What additional information would be helpful to be able to <u>classify the objects</u>? What questions would we need to ask to find out this information?

In the space below, work with your group to ask as many questions as you can pertaining to the following statement:

Within our solar system there are different bodies such as planets, dwarfs planets, moons, comets, asteroids, and meteoroids.

Asking Questions Guidelines:

- Ask as many questions as you can.
- Do not stop to discuss, judge, or answer any questions.
- Write questions exactly as they are stated.
- Change any statements to questions.

As a group, decide on THREE of the questions that you consider to be PRIORITY questions. Write those questions below.

Priority Questions:

1. ____

____

2. ____

____

3. ____

____

Why did your group choose those three questions? Explain your rationale.

____

____

____

3. Current Solar System Classification

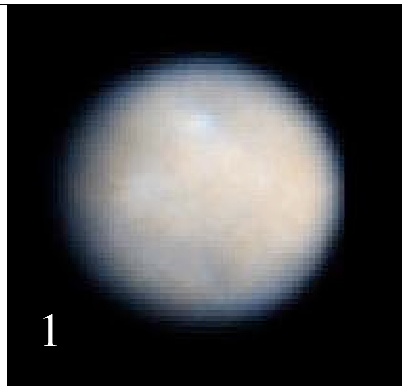
	What Do We Need To Know?			
	Question 1:	Question 2:	Question 3:	Question 4:
Planet				
Dwarf Planet				
Moon				

Asteroid				
Comet				
Meteor				

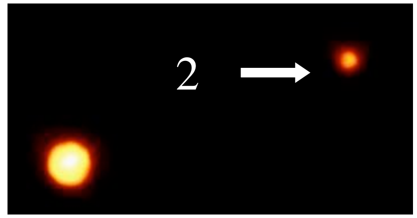
4. What other important information did you find that would help classify the bodies but is not included in the table above? Use the space below to write additional important information that you found that did not fit into any of the categories in the table.

5. Based on the information that you have gathered, have you changed your mind about how to classify the object in the picture at the beginning of the lesson? Explain your reasoning.

6. Recently, some scientists have decided that there should be yet another new definition for a planet. New Definition: Round objects in space that are smaller than stars.
How would this change our current classification system?

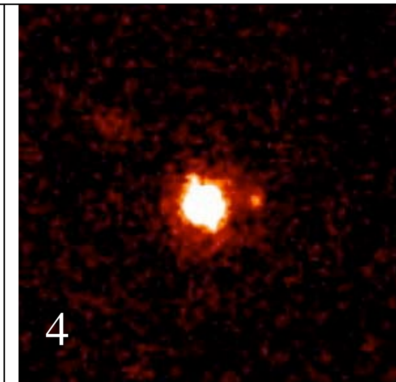


Diameter: 590 miles (950 km)
Distance to Sun: 257 million miles (414 million km)
Orbits: # 18
Composition: Outer layer probably ice and frozen ammonia, no atmosphere



Diameter: 750 miles (1200 km)
Distance to Sun: 4 billion miles (6 billion km)
Orbits: #16 (also shown here)
Composition: Unknown, but surface likely covered in ice, no atmosphere

Diameter: 8,000 miles (13,000 km)
Distance to Sun: 93 million miles (150 million km)
Orbits: #18
Composition: Rock, minerals, surface water, oxygen & nitrogen atmosphere

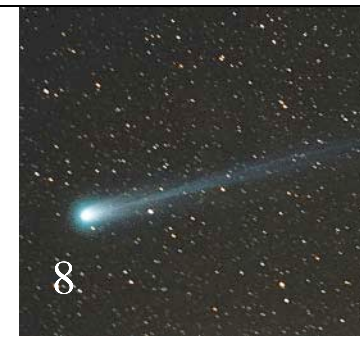


Diameter: 1,500 miles (2400 km)
Distance to Sun: 4–9 billion miles (6-14 billion km)
Orbits: #18
Composition: Probably covered in some kind of ice, frozen atmosphere

Size: 21 x 8 miles (33 x 13 km)
Distance to Sun: 145 million miles (233 million km)
Orbits: #18
Composition: Rocky, but exact composition unknown, no atmosphere

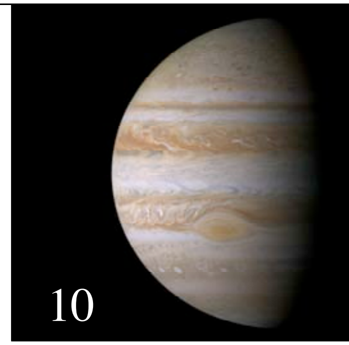
Diameter: 1,940 miles (3,122 km)
Distance to Sun: 484 million miles (779 million km)
Orbits: #10
Composition: Rock, covered in thin layer of ice, thin atmosphere

Diameter: 10 x 5 miles (16 x 8 km)
Distance to Sun: 46 million-3 billion miles (74 million – 4.8 billion km)
Orbits: #18
Composition: Ices and minerals



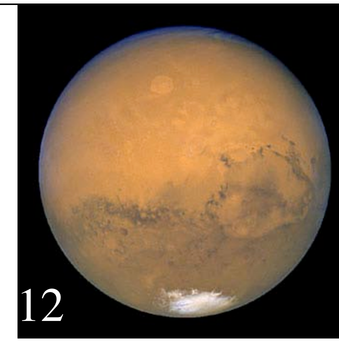
Diameter: 2.5 miles (4 km)
Distance to Sun: 23 million miles (37 million km) to about 1 light year (6 trillion miles; 10 trillion km)
Orbits: #18
Composition: Ices and minerals

Size: 36 x 14 miles (58 x 23 km)
Distance to Sun: 266 million miles (428 million km)
Orbits: #18
Composition: Rocky, no atmosphere



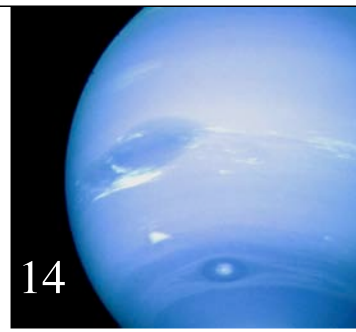
Diameter: 89,000 miles (143,000 km)
Distance to Sun: 483 million miles (777 million km)
Orbits: #18
Composition: Hydrogen & helium gas

Diameter: 2,159 miles (3,474 km)
Distance to Sun: 93 million miles (150 million km)
Orbits: #3
Composition: Rock, no atmosphere

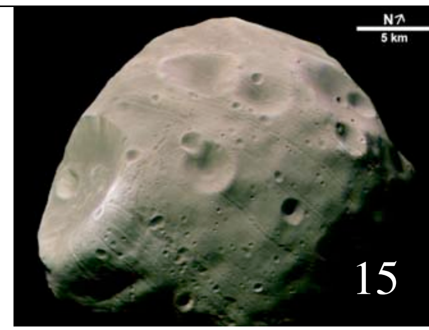


Diameter: 4,222 miles (6,795 km)
Distance to Sun: 142 million miles (229 million km)
Orbits: #18
Composition: Rock, iron, thin carbon dioxide atmosphere

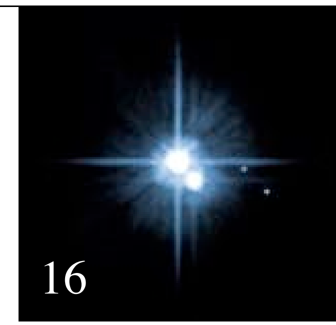
Diameter: 37 x 29 (59 x 47 km)
Distance to Sun: 245 million miles (394 million km)
Orbits: #18
Composition: Carbon, rock, no atmosphere



Diameter: 31,000 miles (50,000 km)
Distance to Sun: 2.8 billion miles (4.5 billion km)
Orbits: #18
Composition: Methane ice in the interior and methane gas in the atmosphere

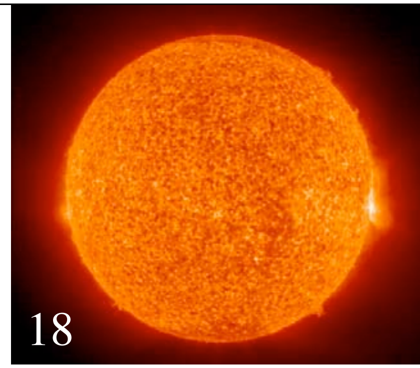


Diameter: 13 miles (21 km)
Distance to Sun: 142 million miles (229 million km)
Orbits: #12
Composition: Rock, carbon, ice, no atmosphere

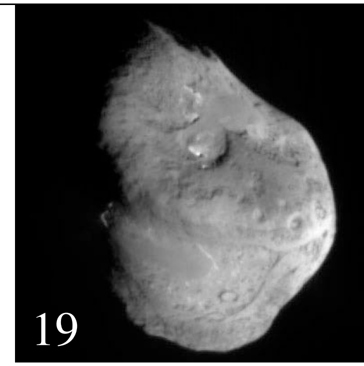


Diameter: 1,423 miles (2,290 km)
Distance to Sun: 3-5 billion miles (5-8 billion km)
Orbits: #18
Composition: Probably rock and frozen nitrogen, thin nitrogen atmosphere

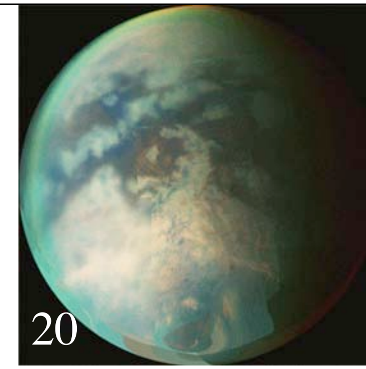
<u>Diameter</u>: 75,000 miles (121,000 km)
<u>Distance to Sun</u>: 886 million miles (1.4 billion km)
<u>Orbits</u>: #18
<u>Composition</u>: Hydrogen and helium gas, sulfur atmosphere



<u>Diameter</u>: 870,000 miles (1.4 million km)
<u>Distance to Sun</u>: n/a
<u>Orbits</u>: center of the Milky Way Galaxy
<u>Composition</u>: Hydrogen gas



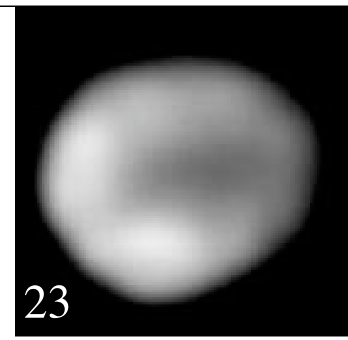
<u>Diameter</u>: 5 x 3 miles (8 x 5 km)
<u>Distance to Sun</u>: about 140 million miles (225 million km)
<u>Orbits</u>: #18
<u>Composition</u>: Ices and minerals



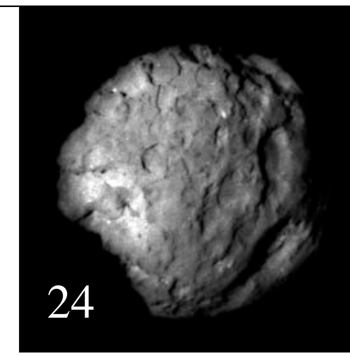
<u>Diameter</u>: 3,200 miles (5,150 km)
<u>Distance to Sun</u>: 886 million miles (1.4 billion km)
<u>Orbits</u>: #17
<u>Composition</u>: Ice & rock, thick nitrogen atmosphere

<u>Diameter</u>: 1,700 miles (2,700 km)
<u>Distance to Sun</u>: 2.8 billion miles (4.5 billion km)
<u>Orbits</u>: #14
<u>Composition</u>: Ice, probably no atmosphere

<u>Diameter</u>: 7,500 miles
<u>Distance to Sun</u>: 67 million miles (107 million km)
<u>Orbits</u>: #18
<u>Composition</u>: Rock& minerals, thick carbon dioxide atmosphere with clouds of sulfuric acid



<u>Diameter</u>: 330 miles (531 km)
<u>Distance to Sun</u>: 219 million miles (353 million km)
<u>Orbits</u>: #18
<u>Composition</u>: Rock, no atmosphere



<u>Diameter</u>: 3 miles (5 km)
<u>Distance to Sun</u>: 140-480 million miles (225-772 million km)
<u>Orbits</u>: #18
<u>Composition</u>: Ices & minerals, no atmosphere

Solar System Card Sorting: Key to the Images

1. **Ceres, dwarf planet** – The largest member of the Asteroid Belt, Ceres is now classified as a dwarf planet. Ceres' round shape suggests that its interior is layered like those of terrestrial planets, such as Earth. Ceres may have a rocky inner core, an icy mantle, and a thin, dusty outer crust. The Dawn mission will tell us more about Ceres.
Image credit: NASA, ESA, J. Parker (Southwest Research Institute), P. Thomas (Cornell University), L. McFadden (University of Maryland, College Park), and M. Mutchler and Z. Levay (STScI)

2. **Charon, satellite of Pluto** – Charon is not currently classified as a dwarf planet, like Pluto. The Pluto-Charon system has a center of gravity outside of the surface of either object, making it a unique case of a gravitational double system, or a binary planet. This is an issue that was not clearly resolved by the IAU vote. If Pluto is a dwarf planet is Charon one too?
Image credit: Dr. R. Albrecht, ESA/ESO Space Telescope European Coordinating Facility; NASA

3. **Earth, planet –** Earth is one of the four terrestrial (rocky) planets of the inner solar system (like Mercury, Venus, and Mars) and the only planet known to have life. *Image credit:* NASA Goddard Space Flight Center

4. **Eris, dwarf planet –** Eris was formerly known as 2003 UB313, also sometimes called the "tenth planet" and is now considered a dwarf planet. Its discovery in 2003 is part of what sparked the latest debate over the definition of a planet, since it is larger than Pluto and orbiting beyond Pluto's orbit in the region of the Solar System know as the Kuiper Belt.
Image credit: W.M. Keck Observatory

5. **Eros, asteroid** – Eros is a member of the asteroid belt. In February 2000, it was visited by the robotic spacecraft NEAR-Shoemaker, which showed that Eros is a single uniform body and probably formed in the very early years of the Solar System. Image credit: *NEAR Project, NLR, JHUAPL, Goddard SVS, NASA*

6. **Europa, satellite of Jupiter** – Europa is Jupiter's 4th largest moon. When the Galileo spacecraft visited Jupiter, the orbiter sent back hundreds of images of the moons, showing evidence of liquid water under the surfaces of Europa, Ganymede and Callisto. *Image credit: NASA/JPL*

7. **Halley, comet –** The nucleus of a comet if like a dirty snowball. Comets come from a very cold region in the far reaches of our Solar System, called the Oort Cloud, and spend most of their time far from the Sun. When they do come close to the Sun, some of the ice in the nucleus burns off, producing the bright tail that we can see from Earth. The tail can reach 6 million miles in

length! The Giotto spacecraft produced this image. Its mission was to approach Halley and send back the first images of a comet's nucleus. *Image credit: ESA*

8. **Hyakutake, comet** – This image shows Hyakutake as seen from Earth. For an explanation of comets, see Halley above. *Image credit: Adam Block/NOAO/AURA/NSF*

9. **Ida, asteroid** – The Asteroid Belt is a region between the orbits of Mars and Jupiter. Ida is one of the over 100,000 asteroids found there. This image was taken by the Giotto spacecraft on its way to Jupiter. *Image credit: NASA/JPL*

10. **Jupiter, planet** – Jupiter is the largest planet in the Solar System. It is one of the four gas giants (like Saturn, Uranus, and Neptune), meaning it has no solid surface on which you could walk. There are many storms in the clouds of its atmosphere, including the famous Great Red Spot. *Image Credit: NASA/JPL/Space Science Institute*

11. **Luna, satellite of Earth** – The Moon is the Earth's only natural satellite. It is made of rock, covered in craters, and has no atmosphere. *Image credit: T.A.Rector, I.P.Dell'Antonio/NOAO/AURA/NSF*

12. **Mars, planet** – Like Merucry, Venus, and Earth, Mars is one of the four terrestrial (rocky) planets in the inner solar system and has the largest volcanoes in the solar system. It gets its reddish color from the iron oxide (rust) on its surface. *Image credit: NASA, J. Bell (Cornell U.) and M. Wolff (SSI)*

13. **Mathilde, asteroid** – Mathilde has probably been involved in some major collisions with meteoroids and other asteroids, producing many craters, including the large central one seen in this image. The Near Earth Asteroid Rendezvous (NEAR) spacecraft produced this image while on its way to Eros. *Image credit: NEAR Spacecraft Team, JHUAPL, NASA*

14. **Neptune, planet** – Like Jupiter, Saturn, and Uranus, Neptune is one of the four gas giants. Its bluish color comes from the methane gas in its atmosphere. *Image credit: JPL, NASA*

15. **Phobos, satellite of Mars** – This is one of Mars' two small moons (the other is Deimos), which were probably asteroids that were trapped by Mars' gravity. Phobos orbits so close to Mars (5,800 km above the surface – our Moon orbits 400,000 km from the Earth!) that it will spiral in toward the planet and eventually (in about 100 million years) crash into Mars or be crushed by the force. The debris will create a ring around Mars. *Image credit: G. Neukum (FU Berlin) et al., Mars Express, DLR, ESA*

16. **Pluto, dwarf planet –** Pluto, smaller than the Earth's Moon and with a highly eccentric and tilted orbit, is classified as a dwarf planet. It is also one of the largest Kuiper Belt Objects (KBOs). The Kuiper Belt is a disk-shaped region beyond the orbit of Neptune. Over 800 KBOs have been discovered so far.
Image credit: NASA, ESA, H. Weaver (JHU/APL), A. Stern (SwRI), and the HST Pluto Companion Search Team

17. **Saturn, planet –** Saturn is also a gas giant (like Jupiter, Uranus, and Neptune). It is known for its magnificent ring system, though the other gas giants have rings as well.
Image credit: CICLOPS, JPL, ESA, NASA

18. **Sol, star –** Sol, our Sun, is the only star in our solar system. The planets and other solar system objects orbit the Sun.
Image credit: SOHO

19. **Tempel 1, comet –** The Deep Impact spacecraft produced this image about 5 minutes before smashing into the comet's surface. NASA sent the spacecraft to find out more about the comet and the craters on its surface. For more about comets, see Halley above. *Image credit: NASA/JPL-Caltech/UMD*

20. **Titan, satellite of Saturn –** Titan is Saturn's largest moon. Its diameter is 3,200 miles, the size of the United States! It is the only moon in the solar system with a thick atmosphere. *Image credit: NASA/JPL/University of Arizona*

21. **Triton, satellite of Neptune –** Triton is covered in ice and may have a weak atmosphere, meaning it could possibly be suitable for life. *Image credit: NASA*

22. **Venus, planet –** Venus, like Mercury, Earth, and Mars, is one of the terrestrial (rocky) planets in the inner solar system.
Image credit: *Magellan Project, JPL, NASA*

23. **Vesta, asteroid –** Vesta has an interesting surface with clear light and dark regions, unlike most other asteroids, meaning that it is made up of many different elements. *Image credit: STScI, B.Zellner(GA Southern Univ.), NASA*

24. **Wild 2, comet –** The Stardust mission spacecraft produced this image of Wild (pronounce "Vilt") 2, while passing close to the comet in order to collect samples of the interstellar dust from the comet. *Image credit: Stardust/NASA/JPL*

Solar System Object Categories

Star – A star is a giant ball of gas that gives off energy (light) due to thermonuclear reactions. Our Sun is the only star in the Solar System, but is one of about 200 billion stars in the Milky Way Galaxy.

Planet – According to the resolution passed by the International Astronomical Union (IAU) in 2006:

A planet is a celestial body that

(a) is in orbit around the Sun,
(b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, and
(c) has cleared the neighborhood around its orbit.

Dwarf Planet - According to the resolution passed by the IAU in 2006:

A "dwarf planet" is a celestial body that

(a) is in orbit around the Sun,
(b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape,
(c) has not cleared the neighborhood around its orbit, and
(d) is not a satellite.

Moon / Satellite – A satellite (moon) is an object that orbits around a planet or dwarf planet.

Comet – A comet is a small body that orbits the Sun, usually with a highly elliptical orbit, and that exhibits a coma (atmosphere) and tail when it approaches the Sun. Comets belong to a bigger category known as "Small Solar System Bodies," a term introduced by the IAU in 2006.

Asteroid – An asteroid is a small body that orbits the Sun, usually within the Asteroid Belt, a region of the Solar System between the orbits of Mars and Jupiter. Asteroids also belong to the category "Small Solar System Bodies" (see "Comet" above) and have also been referred to as minor planets. All the asteroids put together would only have a diameter about half that of the Earth's Moon.

Sorting the Solar System

What's this activity about?

Big Questions:

- What types of objects are in our Solar System?
- Why do the definitions of the objects change?

Big Activities:

- Using images of Solar System objects, start discussions of the characteristics of asteroids, comets, planets, and moons.
- Practice scientific thinking by sorting objects into categories according to their common qualities.

Participants:

From the club: A minimum of one person.
With larger groups, up to four presenters can participate.

Visitors: This activity is appropriate for families, the general public, and school groups ages 10 and up. With small groups, one set of cards can be used. Four sets are included for use in classrooms or larger groups.

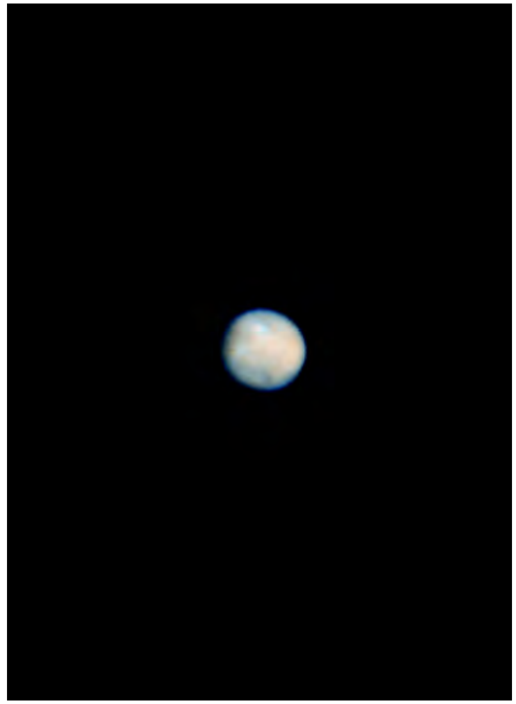
Also, a large set of objects is included in this manual. You may print them yourself, but it is recommended that you do this at a print shop. Printing them requires a lot of ink.

Duration:

Ten minutes, up to a half hour, depending on the depth of questions and conversation.

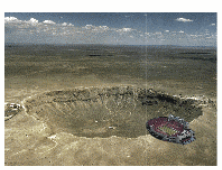
Topics Covered:

- Review of the diversity of objects in our Solar System
- How scientists use common characteristics to classify the world around us



Barringer Crater

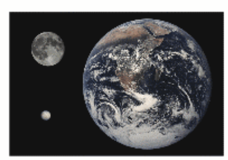
- This crater is located in Arizona, USA
- It was created 50,000 years ago by a chunk of **METAL** from space
- It measures about **1.2 km** in diameter



Size of crater compared to a stadium

Ceres

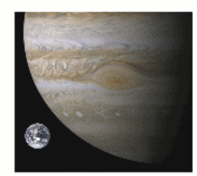
- Ceres is the largest object between the orbits of Mars and Jupiter
- It is made mostly of **ROCK** and **ICE**
- Ceres is about **950 km** in diameter



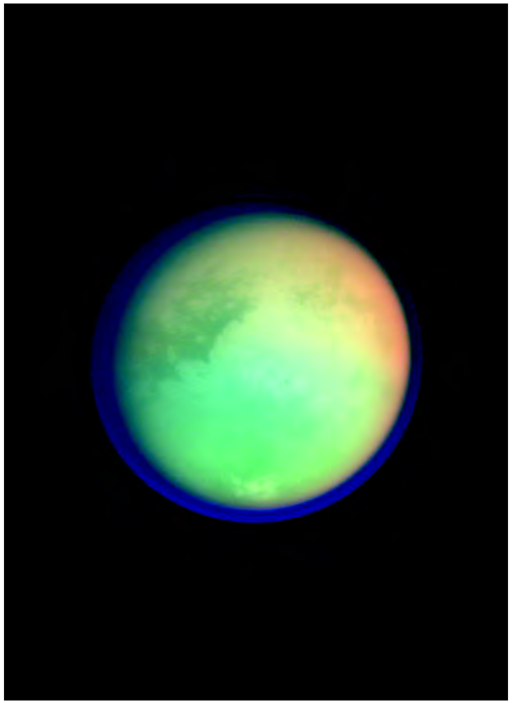
Ceres (bottom left) compared to the Earth and Moon

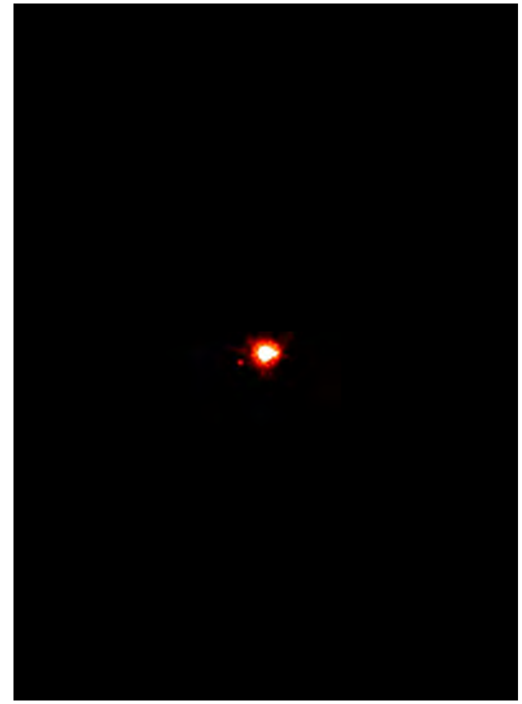
Earth

- It orbits the Sun between Venus and Mars
- Earth is made of **ROCK**, a **METAL** core and both solid and liquid **ICE** (water, that is) on its surface
- Its diameter is **12,650 km**



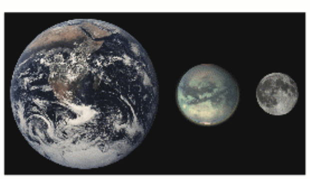
Size of Earth compared to Jupiter





Titan

- Titan orbits Saturn
- It is made of **ROCK** and **ICE** and has a thick atmosphere
- It is **5,150 km** in diameter, between the size of the Earth and Moon



Size of Titan (center) compared to the Earth and Moon

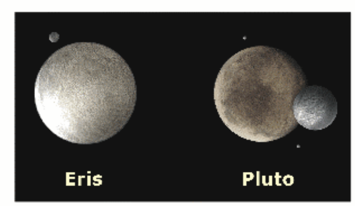
Wild 2

- Wild 2 orbits the Sun between Mars and Jupiter, though its orbit used to be much more distant
- It is made of **ICE** and **DUST**
- It is about **4 km** across

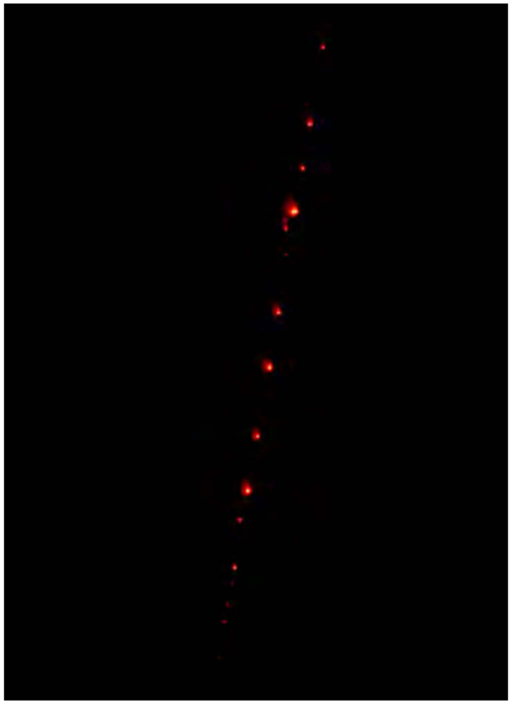
Size of Wild 2 compared to Manhattan

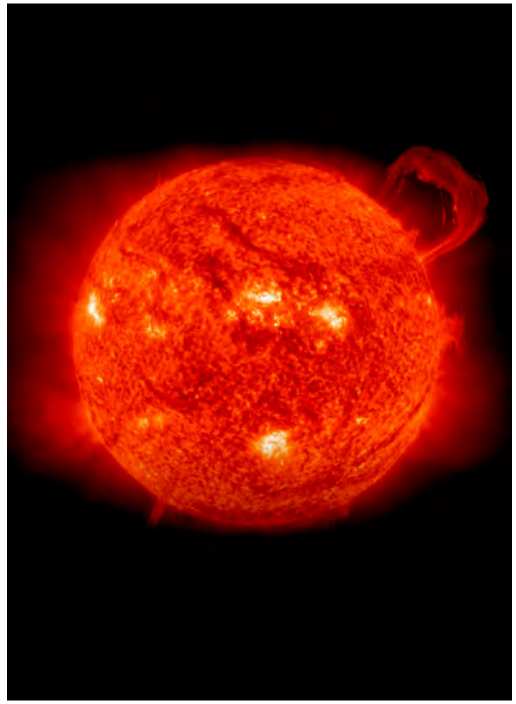
Eris

- The orbit of Eris is very distant, mostly beyond Pluto's orbit.
- It is made of **ICE** and **ROCK**
- The diameter of Eris is about **2,600 km**



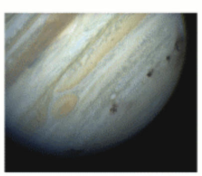
Size of Eris compared to Pluto





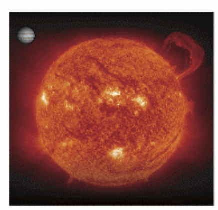
Shoemaker-Levy 9

- Its orbit originally took it beyond Pluto. After it was captured by Jupiter's gravity, it was torn apart and eventually smashed into Jupiter.
- Made of ICE and ROCK
- Largest pieces were **1km** and left huge marks on Jupiter



Sun

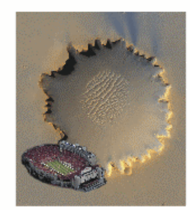
- The Sun is located in the center of our Solar System
- It is made mostly of hydrogen and helium GAS
- The Sun is **1.4 million km** in diameter



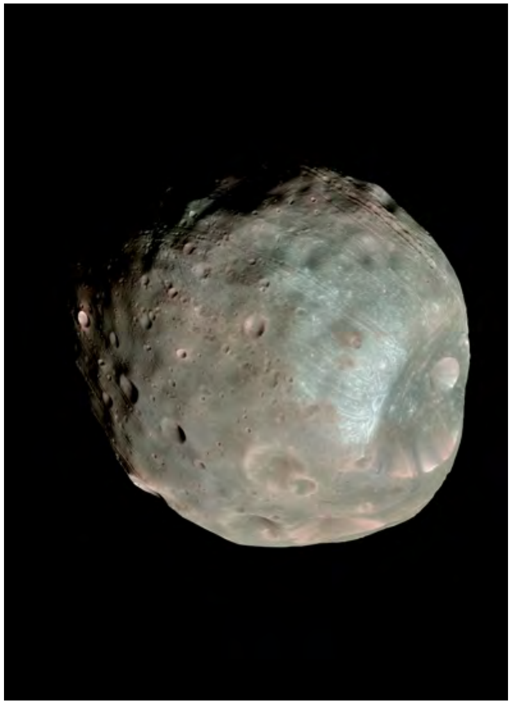
Size of Sun compared to Jupiter

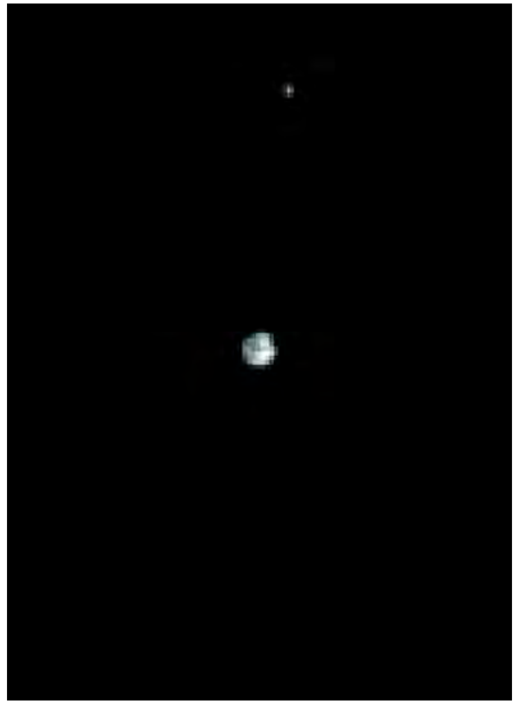
Victoria Crater

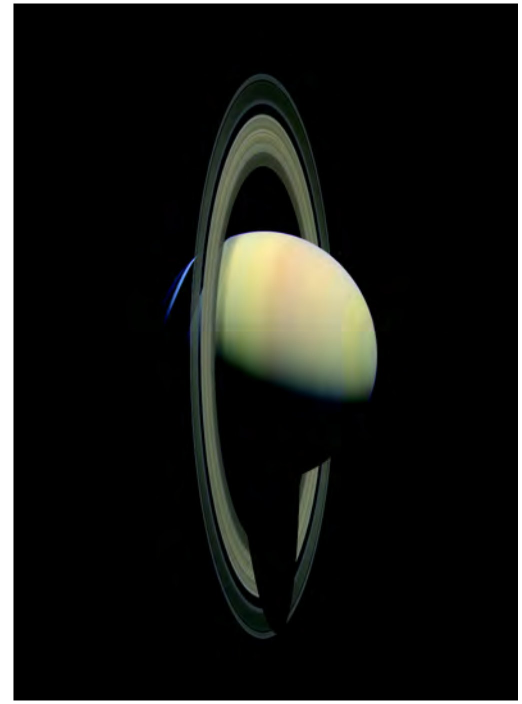
- This crater is one of the smaller craters on Mars
- The rim's jagged edges are due to erosion caused by ROCK and DUST
- It is **750 meters** across



Size of crater compared to a stadium

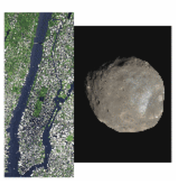






Phobos

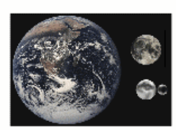
- Phobos closely orbits Mars and will eventually collide with it
- It is mostly made of **ROCK** but may have **ICE** inside
- Phobos is about **11 km** across



Size of Phobos compared to Manhattan

Pluto & Charon

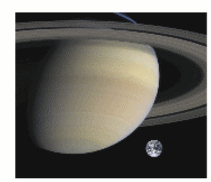
- Pluto and Charon orbit orbit each other, together are mostly outside Neptune's orbit
- These round objects are made of **ICE** and **ROCK**
- Pluto is about **2,300 km** across



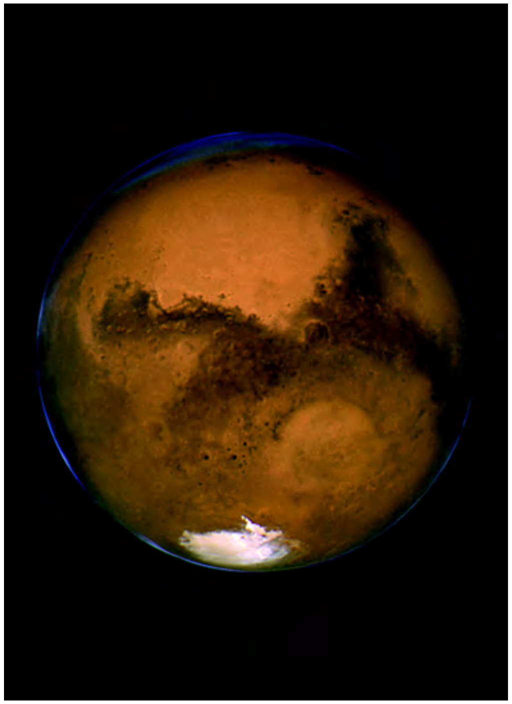
Size of Pluto & Charon compared to Earth and Moon

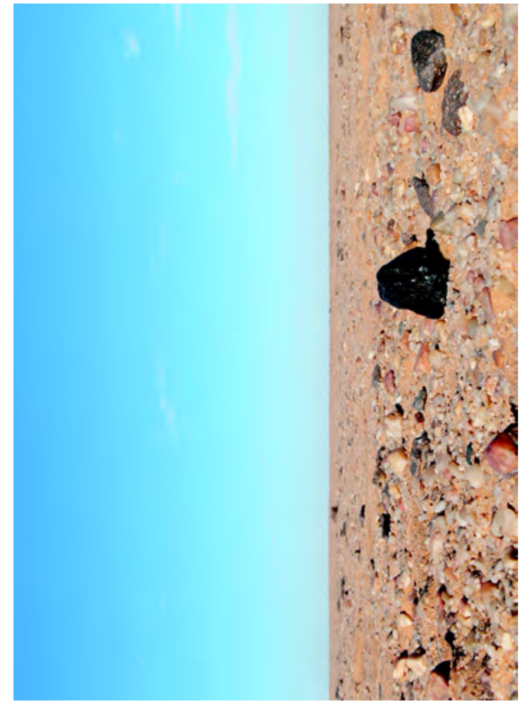
Saturn

- Saturn orbits the Sun between Jupiter and Uranus
- Saturn is mostly made of **GAS**
- The main body is **120,000 km** across



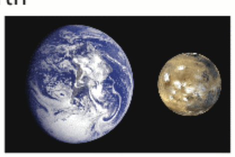
Size of Saturn compared to Earth





Mars

- The orbit of Mars is between Earth and the Asteroid Belt
- Mars is made of **ROCK** with a **METAL** core and some solid **ICE** on its surface
- It is **6,800 km** in diameter, about half as wide as the Earth



Size of Mars compared to Earth

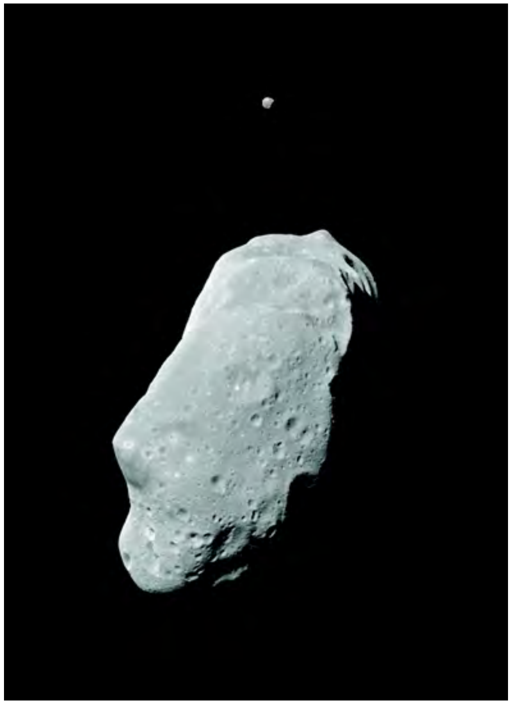
Meteor

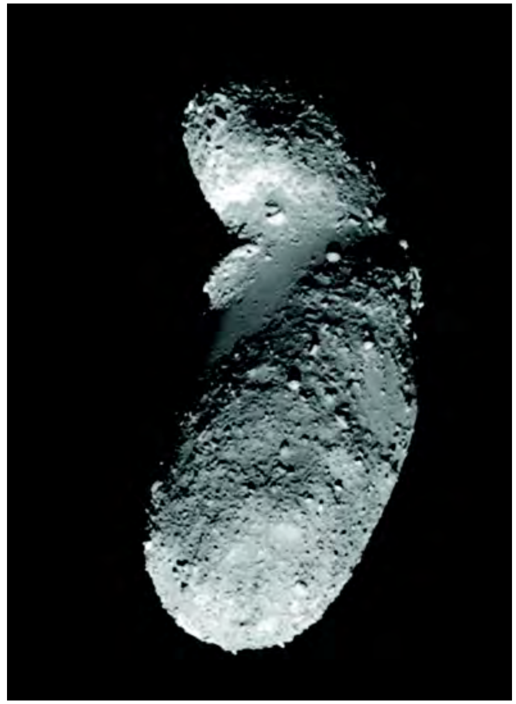
- Meteors occur in Earth's atmosphere, about 75km above the surface
- We see the glowing pieces of **ROCK**
- The pieces of rock are mostly less than **1cm**, or the size of a coin

Size of rock compared to a coin

Meteorite

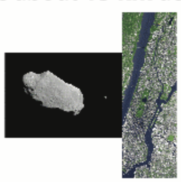
- Meteorites are pieces of asteroids that land on other worlds
- They are made of **METAL** and **ROCK**
- Almost all meteorites on Earth are smaller than **1 meter**





Ida and Dactyl

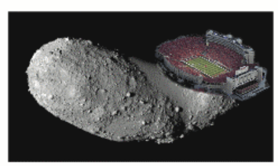
- Together they orbit the Sun between the orbits of Mars and Jupiter. Dactyl (the smaller object) orbits Ida.
- They are mixtures of **ROCK** and **METAL**
- Ida is about **15 km** across



Size of Ida compared to Manhattan

Itokawa

- Itokawa's orbit crosses the orbits of Earth and Mars but is not a threat to either
- It is made of a loose pile of boulders made of **ROCK** and **METAL**
- Its longest side is **535 meters**

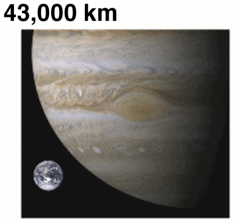


Size of Itokawa compared to a stadium

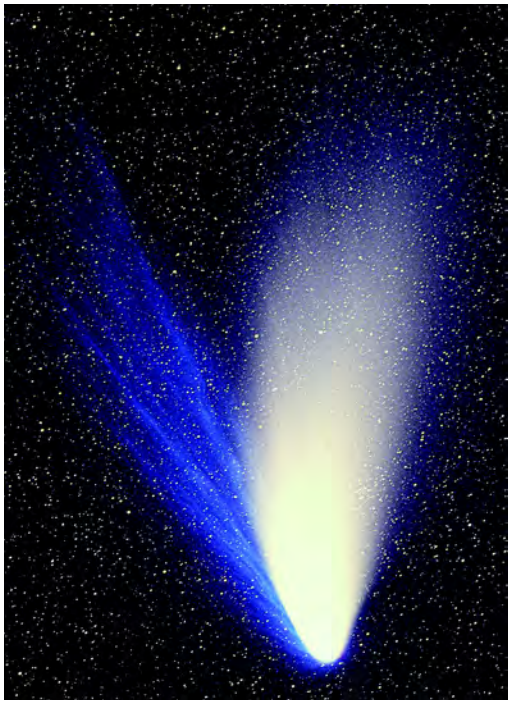
Jupiter

- Jupiter orbits the Sun between the Asteroid Belt and Saturn
- It is made of **GAS**
- Its diameter is about

143,000 km

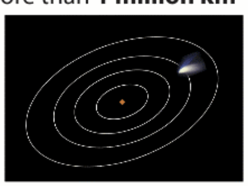


Size of Jupiter's Red Spot compared to Earth



Hale-Bopp

- Hale-Bopp orbits between Earth's orbit and the distant Solar System — far beyond the orbit of Pluto
- Hale-Bopp is made of ICE and DUST
- The tail shown here extends more than **1 million km**



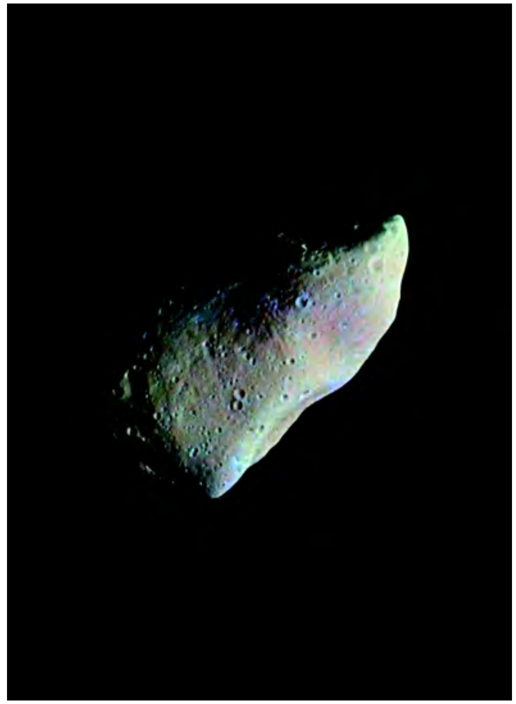
Hoba

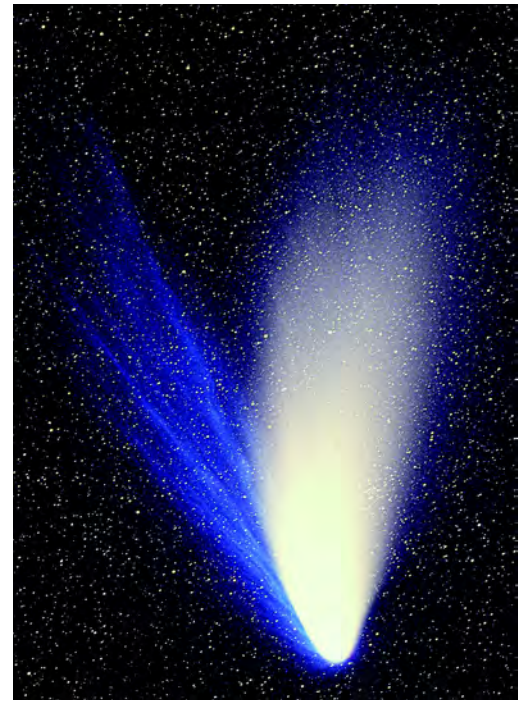
- This object landed on Earth 80,000 years ago in what is now the country of Namibia
- Hoba is made of METAL
- It measures about **3 meters** across

Iapetus

- Iapetus orbits Saturn
- This walnut-shaped object is made of ICE with some ROCK
- It is **1,500 km** across, or about half as wide as the Earth's Moon

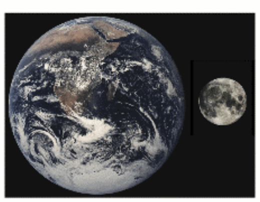
Size of Iapetus compared to Moon





Earth's Moon

- The Moon orbits Earth
- It is made of **ROCK** with a small **METAL** core
- The Moon is **3,500 km** in diameter or about ¼ the width of Earth



Size of Moon compared to Earth

Gaspra

- This object orbits the Sun between Mars and Jupiter
- It is made of a mixture of **ROCK** and **METAL**
- It is **18 km** on the longest side

Size of Gaspra compared to Manhanttan

Hale-Bopp

- Hale-Bopp orbits between Earth's orbit and the distant Solar System — far beyond the orbit of Pluto
- Hale-Bopp is made of **ICE** and **DUST**
- The tail shown here extends more than **1 million km**

Key to Sorting the Solar System Cards

Object	Description	Size (km)	Picture Credits
Barringer Crater	Also known as Meteor Crater, it is located in Arizona, USA. Created by the impact of a meteorite about 50,000 years ago, this crater was formed before humans inhabited the Americas.	1.2	B.P. Snowder
Ceres	Ceres is the largest object in the Asteroid Belt. The International Astronomical Union classifies Ceres as a Dwarf Planet. It is the target of the Dawn spacecraft in 2015.	950	NASA, ESA, J. Parker (SwRI) et al.
Earth	Earth is the third planet from the Sun and is the fifth largest planet in the Solar System. About 71% of Earth's surface is water, the remainder consists of land.	12,650	Taken from Apollo 17 in 1972, credit NASA
Earth's moon	The moon is the fifth largest satellite in the Solar System. It is the only celestial body on which humans have landed. Although it appears bright in the sky, it is actually as dark as coal.	3,500	NASA/JPL/USGS
Eris	Eris is a Dwarf Planet with a moon called Dysnomia. It is more massive than Pluto and orbits the Sun three times farther. It was discovered in 2005 and caused a stir after initially being described as the 10th planet.	2,600	NASA/ESA/M. Brown
Eros	Eros was the first near-Earth asteroid discovered. It is also one of the largest. The probe NEAR Shoemaker landed on this asteroid in 2001. Eros orbits between Earth and Jupiter, crossing Mars's orbit.	34	NASA/JPL/JHUAPL
Gaspra	Gaspra is an asteroid that orbits the inner edge of the main Asteroid Belt. The Galileo spacecraft flew by Gaspra on its way to Jupiter.	18	NASA/JPL/USGS
Hale-Bopp	Hale-Bopp was one of the brightest and most widely viewed comets of the 20th century. It came into the inner Solar System in 1997 and has an orbital period of over 4,000 years.	1,000,000	E. Kolmhofer, H. Raab; Johannes-Kepler-Observatory
Hoba	The Hoba meteorite is the largest known meteorite on Earth. It landed here about 80,000 years ago in what is now Namibia. Hoba weighs over 60 tons and is the most massive piece of naturally-occurring iron on Earth's surface.	0.003	Patrick Giraud
Iapetus	Iapetus is the third largest moon of Saturn. It has an equatorial ridge that makes it look a bit like a walnut, as well as a light and a dark side. Astronomers think that the dark side is covered with a thin layer of residue from the icy surface sublimating.	1,500	NASA/JPL/Space Science Institute
Ida and Dactyl	Ida is a main belt asteroid and the first asteroid found to have a moon, Dactyl. It was imaged by the Galileo spacecraft on its way to Jupiter.	15	NASA/JPL
Itokawa	Asteroid Itokawa crosses the orbits of both Mars and Earth. It is a rubble pile of rocks. In 2005, the Hayabusa probe landed on Itokawa to collect samples.	0.5	ISAS, JAXA
Jupiter	Jupiter is the largest planet in the Solar System, more massive than all the other planets combined. This gas giant has been explored by many spacecraft, notably the Galileo orbiter. It has four large moons and dozens of smaller moons.	70,000	NASA/JPL/University of Arizona

Night Sky Network Resources
You can print your own cards here:
http://nightsky.jpl.nasa.gov/download-view.cfm?Doc_ID=459

Key to Sorting the Solar System Cards

Object	Description	Size (km)	Picture Credits
Mars	Mars is the fourth planet from the Sun. Iron oxide gives it a reddish appearance. It has polar ice caps and a very thin atmosphere. Two tiny moons might be captured asteroids.	6,800	NASA
Meteor	Small pieces of asteroids or comets collide with Earth's atmosphere to create meteors. The compressed air in front of the rock heats up, causing it to glow and leave a trail of ionized gas.	0.00001	Chuck Hunt
Meteorite	Most meteorites are pieces of the Asteroid Belt that land on Earth's surface. Over 90% of meteorites are considered stony meteorites. About 5% are iron meteorites. Both types contain a significant about of iron.	0.001	Dr. Svend Buhl www.meteorite-recon.com
Phobos	Phobos is the largest moon of Mars, but still quite small. It is likely a captured asteroid and will break up and crash into Mars in the next 40 million years.	11	NASA/JPL-Caltech/University of Arizona
Pluto and Charon	Pluto is the 2nd largest dwarf planet in the Solar System (after Eris). It has a large moon Charon and two smaller moons, Nix and Hydra. Pluto and Charon are sometimes treated as a binary system since their center of gravity is between the two.	2,300	ESA/ESO/NASA
Saturn	Saturn is the second largest planet in the Solar System. It is made of gas and has very thin icy rings. It also has dozens of moons. The Cassini-Huygens spacecraft has been orbiting Saturn since 2004.	120,000	NASA/JPL/Space Science Institute
Shoemaker-Levy 9	Comet Shoemaker-Levy 9 provided the first direct observation of the collision of extraterrestrial solar system objects. It broke into many fragments, called the "String of Pearls," and impacted Jupiter in 1994.	1	NASA/HST
Sun	The Sun is the star at the center of our Solar System, about 150 million km from Earth. It contains 99.9% of all the mass in our Solar System. It travels once around the Milky Way Galaxy in about 250 million years.	1,400,000	ESA/NASA/SOHO
Titan	Titan is the largest moon of Saturn, comprising 96% of the mass of all Saturn's moons combined. It is a cold world with a thick nitrogen atmosphere and liquid methane lakes on its surface. The Huygens probe landed on its surface in 2005 and took pictures of icy conditions.	5,150	NASA/JPL/Space Science Institute
Victoria Crater	This impact crater near the equator of Mars was visited by the Mars Exploration Rover *Opportunity*. The scalloped edges of the crater are caused by erosion. Although Mars has very little atmosphere, it does have dust storms.	0.75	NASA/JPL-Caltech/University of Arizona/Cornell/Ohio State University
Wild 2	Comet Wild 2 is officially named 81P/Wild. It once orbited beyond Jupiter but got too close to the giant planet in 1974 and was tugged into a smaller orbit between Jupiter and Mars. The Stardust sample return mission took pictures and captured some of the comet's coma in 2004.	4	NASA/JPL-Caltech

Helpful Hints

Common *misconceptions* addressed by these resources:

- The Solar System contains more than one star
- The planets are the only things in our Solar System
- Science is a rigid set of facts to be memorized

Other Games:

Sort It:
With a group of 20+, give each person a card and ask them to sort themselves by size, distance from the Sun, common materials, alphabetically, or shape. There may be more than one way to sort. All reasonable attempts should be accepted.

With smaller groups, each person (or group of up to 3 people) gets their own deck to answer the same questions. The first group to sort them correctly wins. Allow each group to finish and hold their hand up when they're done. Once they raise their hand, they can't change their order. If the first group has anything out of order, go to the second, and so forth.

20 Questions:
Have the presenter pick an object but don't tell the visitors. Let the visitors take turns asking yes/no questions until they guess the object. The person who guesses correctly gets to pick the next object. Give time during games and between rounds for visitors to look at the backs of the cards.

Background Information

This activity was adapted from a classroom activity originally developed by Anna Hurst Schmitt for the Teacher's Newsletter Universe in the Classroom:
http://www.astrosociety.org/education/publications/tnl/70/pluto.html - 10

For a history of the definition of a planet, see these websites:
http://www2.ess.ucla.edu/~jlm/epo/planet/planet.html

http://www.astrosociety.org/education/publications/tnl/70/pluto.html

http://www6.cet.edu/dawn/multimedia/makeplanet.asp

Detailed Activity Description

Sorting Our Solar System

Misconception Tip: Many people don't understand the difference between Solar System, Galaxy and Universe. Here is a chance to talk at length about the smallest of these scales.
Presentation Tips: These cards can be used to illustrate many points. The activity described here is one example, but you may find others that work in different situations. You can also find other ideas in the "Helpful Hints" section. Using more than one deck and breaking visitors into small groups can be interesting because they see that there are different ways to categorize the same objects. If you would like to use more than one set of cards, it is recommended that you print them on various color card stock. The individual sets get easily combined into a single pile if they are all one color.
Before you get started: Remove the Ceres card from the deck and put in your pocket. You will bring this out later.

Leader's Role	**Participants' Role (Anticipated)**
To say: What kinds of things do we find in our Solar System?	Planets, stars, people, airplanes
Ahh! How many stars are there in our Solar System?	Billions and billions
There is actually only one star in our Solar System. The term "Solar System" refers just to our own star, the Sun and everything orbiting it. That includes planets, like you said. What else is in the Solar System that's not here on Earth?	Comets, moons, asteroids
To do: Bring out all of the Solar System Cards, except for Ceres.	
To say: Great! Take a look at this. I've got pictures here that represent a sample of the different kinds of objects found in our Solar System. Now, you can't tell how big each object is just from the picture. Some pictures are taken close up and others from far away. You'll want to check the backs of the cards to see how big each object is. What else does the back of the card tell us?	Where it is, what it's made of, how big it is
To do: Pick up one of the cards (in the following example, we are using Gaspra)	
To say: Scientists sort things by their physical characteristics. What are some characteristics of this object? Can you describe what it looks like? 	It's lumpy. And brown, and has craters

<table>
<tr><th>Leader’s Role</th><th>Participants’ Role (Anticipated)</th></tr>
<tr><td>
<u>To say:</u>
Great! We also know from the information on the back that it's as big as a city and that it orbits the Sun between Mars and Jupiter. These are characteristics too.

Now it's your turn to be the scientist. Work together to sort these objects into some categories using their characteristics. Get creative! You get to choose the categories.</td><td>

Participants sort the cards into various groups.</td></tr>
<tr><td colspan="2">
<u>Presentation Tip:</u>
If you are working with a large group, give each person a card and have them sort themselves into categories. This can be very fun and collaborative!</td></tr>
<tr><td>
<u>To say:</u>
There are no limits to the number of categories you can have. But think about the characteristics that objects in each of your categories have.

Tell me about the categories you picked.

Did any of the objects fit into more than one category? Tell me why you decided on the category you put them in.

Okay, now where would this object fit?

<u>To do:</u>
Hand the group the Ceres card.

<u>To say:</u>
What characteristics does it share with that group? Could it fit in more than one group?

(Extension) Could you refine your category definitions so that nothing fits in more than one category?</td><td>

Describe groups

Usually they do

Put it in one of the categories

Sometimes the groups are flexible enough</td></tr>
</table>

Leader's Role	**Participants' Role (Anticipated)**
To say: This is great! You are being real scientists. This is exactly what biologists, chemists, geologists, and astronomers do. And as new bacteria or birds or fossils are found, they use their knowledge of what has already been discovered to help them think about this new object. That's exactly what happened when Eris was discovered. Eris is another Pluto-sized object that's also orbiting way out past Neptune. And many more objects are being found out there all the time. Sometimes new discoveries even cause the definitions to change! The definition of a planet changed in 2006 and a whole new category was created: dwarf planet. That category includes both Ceres and Pluto.	
(If before an observing evening) Can you see any of these categories in the sky right now? Actually, do you see that bright star-like light over there? Well, it's not a star at all. That's Jupiter! Which category does that fit onto?	Sun or Moon or none

Materials

What materials from the ToolKit do I need?

In the activity bag:
At least one set of Solar System Cards (4 sets included in 2 decks)

What must I supply?

- Table or flat surface for organizing the cards, unless you have a big group that can hold one card each

Where do I get additional materials?

You can order additional sets, while supplies last, from the Night Sky Network. For more information, send an email to: nightskyinfo@astrosociety.org

To make additional copies of the cards, just print the following five pages in color, *one-sided* on card stock (or other thick paper).

Cut each page into 3 strips so that the image and description stay together.

Fold each strip in half to make two-sided cards. You can paste them with glue or tape around the edges.

For large groups where each person will hold a single card, you may want to print the large size cards. In that case, simply fold them in half and glue them together, as shown.

This activity can be done with any set of images in any size. The Hubble Site and the NASA Image archive have a wealth of pictures of Solar System objects.

- http://hubblesite.org/newscenter/
- http://www.nasa.gov/multimedia/imagegallery/

Where could I use this activity?

ACTIVITY	Star Party	Pre-Star Party – Outdoors	Pre-Star Party – Indoors	Girl Scouts / Youth Group Meeting	Classroom			Club Mtg	Gen Public Presentation (Seated)	Gen Public Presentation (Interactive)
					K-4	5-8	9-12			
Sorting the Solar System		√	√	√		√	√	√	√	√

What do I need to do before I use this activity?

What materials from the ToolKit are needed for this activity?	What do I need to supply to run this activity that is not included in the kit?	Preparation and Set Up
At least one set of Sorting the Solar System Cards. Four sets are included for use with larger groups.	A table or flat surface is preferred.	Remove the Ceres card from the deck(s). These will be used later.

Tab page front

Label: Obtaining, Evaluating, and Communicating Information

TN Department of Education

Obtaining, Evaluating, and Communicating Information

Tennessee Academic Standards for Science

Teacher Guide for Grade 5

Standard
5.ESS1.2 Research and explain the position of the Earth and the solar system within the Milky Way galaxy, and compare the size and shape of the Milky Way to other galaxies in the universe.

Tennessee Academic Standards for Science: Page 43

Three-dimensional Learning Performance for Lesson
Students will obtain, evaluate, and communicate information* in order to show the position of the Earth and the solar system within the Milky Way galaxy**, highlighting the scale of these components in the universe.***

Science and Engineering Practice for Lesson
*Obtain, Evaluate, and Communicate Information**
Students will synthesize information from a variety of sources, including text, graphs, video, and charts to evaluate the Earth's position in the solar system and the solar system's position within the Milky Way Galaxy. Students will communicate an understanding of the relative scale of the size of the Earth, Solar System, Stellar Neighborhood, and Milky Way Galaxy through writing.

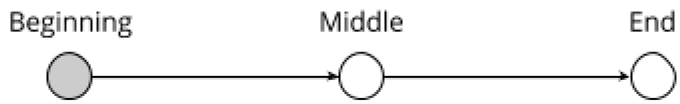
Disciplinary Core Idea for Lesson
*Earth's Place in the Universe***
Earth's Place in the Universe describes the universe as a whole and addresses its grand scale in both space and time. The planet Earth is a tiny part of a vast universe that has developed over a huge expanse of time. Our sun is but one of a vast number of stars in the Milky Way Galaxy, which is one of a vast number of galaxies in the universe.

A Framework for K–12 Science Education: Page 172-173

Crosscutting Concept for Lesson
*Scale, Proportion, and Quantity****
Objects in our universe vary in size from the sub-atomic scale to the incredibly large distances of space. In this activity, students synthesize information from a variety of sources to gradually develop a sense of scale to describe the Earth's place in the universe.

Prior Knowledge

Location Within Instructional Unit



- Concepts that should be covered before this lesson:
    - Earth's place within the solar system
    - Scale of solar system planet sizes and distance
    - Types and classifications of the sun and other stars and basic stellar life cycles
- This lesson covers portions of standard 5.ESS1.2
    - Research and explain the position of the Earth and the solar system within the Milky Way galaxy.

Materials (Listed in Order Needed for Lesson)

- Student Activity Sheet which includes embedded informational text
- https://voyager.jpl.nasa.gov/golden-record/
- https://kisd.de/~krystian/starmap/
- https://imagine.gsfc.nasa.gov/features/cosmic/solar_neighborhood.html
- https://www.nasa.gov/jpl/charting-the-milky-way-from-the-inside-out
- https://www.youtube.com/watch?v=BKT-Z6Dy6TU

Lesson Sequence and Instructional Notes

Introduce students to the Voyager I and Voyager II missions, including the "golden record" through reading of the introductory text on the student activity sheet. The introductory text article is "Voyager 1 and 2: The Interstellar Mission." Teachers may choose to have students read the text in a manner appropriate to their class.

Tell students that you want to show them more about the golden record that was included on the spacecraft. Use the following website: https://voyager.jpl.nasa.gov/golden-record/

- Scroll down and click on "What's on the Record?". There are four circles, each one representing pictures, music, sounds, and greetings respectively. This is the actual information that was chosen by NASA to be included on the golden records.

Explain to students that at the time of the Voyager mission launches, stars known as pulsars had only recently been discovered. It was therefore thought that using pulsars would provide a sort of "road map" to our solar system. In the years since, literally millions of pulsars have been discovered, making the roadmap on the golden record very messy and useless. In addition, there have many changes in technology, engineering, and music since 1977.

Ask students: If NASA wanted to design a new golden record, with the updated location of the planet Earth, what information would we need to include? Have students "turn and talk" with a partner and then share out possible ideas.

Teachers should direct student attention to the activity sheet and begin with the section asking students to mark the Earth's location. Students have already explored the basic components of the solar system in third grade and should be able to mark the "X" on the planet that is in the third orbit from the Sun. In asking for additional information, students might describe the Earth as "terrestrial," "an inner planet," "looks blue and green from space," "contains water," etc. The idea is to communicate in writing additional information for the location of the Earth.

Continue to the next portion of the student activity sheet: "Our Stellar Neighborhood."

Read aloud the text beside of Step 2.

Discuss the table located in the student activity packet. Teachers might want to ask:

Proxima Centauri	4.22 light years (ly)
Barnard's Star	5.97 ly
Wolf 359	7.7 ly
Sirius A & B	8.6 ly
Epsilon Eridani	10.5 ly
Ross 128	10.8 ly
Procyon	11.4 ly
Tau Ceti	11.9 ly
Altair	16.3 ly
Eta Cassiopeiae	19 ly

What is a lightyear? *This is a unit used to measure distances in space. It is the distance that a light beam can travel in one year - a distance of six trillion miles!*

Which star is closest to our sun? *Proxima Centauri*

Why does it say Sirius A and B? *This is actually two stars who are very close to each other.*

Ask students: *What other information do we need to be able to create a map of our stellar neighborhood that would help extraterrestrials to find us?* Brainstorm as a whole class to come up with ideas. Students should write these ideas on the student activity sheet.

Possible ideas:

- *The table lists additional stars and distances, but does not tell us in which direction to place the stars on our diagram.*
- *You could include the sizes of the stars.*
- *You could include the "color" of the stars.*
- *You could point out any patterns that the stars make.*

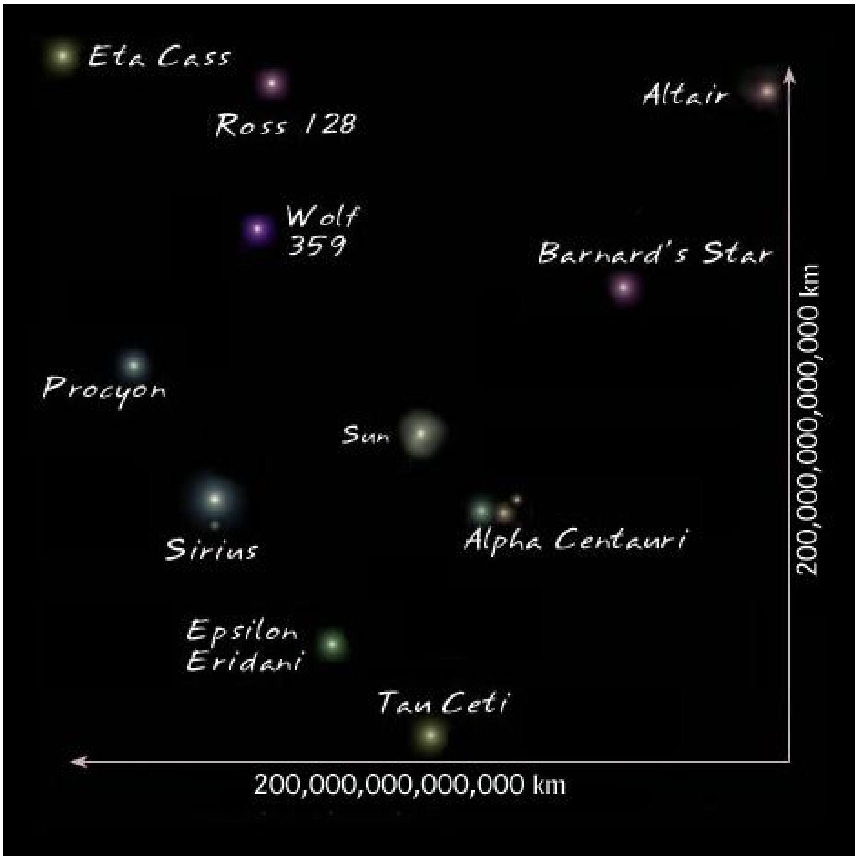
Tell students to turn to the page in their student activity guide with a grid.

Display the following computer model for the students: https://kisd.de/~krystian/starmap/

- This model presents a more realistic idea of our local star neighborhood. Showing it initially in 3D allows students the opportunity to gain some initial understanding of the position of the stars in space.
- Teachers can then rotate to a simplified 2D plane and double click on the animation. This will pause the stars and allow students the opportunity to map stars closest to Earth. The Alpha Centauri system is closest to Earth. A space shuttle traveling at 17,600 mph would take about 165,000 years to reach it.

Model for students how to graph the star location onto the grid. An example of a completed star grid is shown below and is provided for teacher use. Students should translate this graph to show only quadrant one.

The graph below shows a completed grid with a map of the stellar neighborhood. Note that the website above will not show Altair and Eta Cassiopeiae, as they are further than 14 light years away.



After students have successfully mapped the placement of the sun within the context of other stars, they can move to the next part of the student activity sheet: Where is our solar system located within the Milky Way Galaxy?

Students will read the information text titled "The Milky Way Galaxy.". Provide a purpose for reading by asking students to underline information that will be helpful in explaining to extraterrestrials where our solar system is located within the galaxy. Teachers may choose to read this in a manner appropriate for their class. Students will use the text to respond to part 5C below.

Ask students to examine the diagram of the Milky Way Galaxy that is included on their student activity sheet. Teachers might also want to display this for the students to examine. The diagram can be found at this website:

- https://www.nasa.gov/jpl/charting-the-milky-way-from-the-inside-out
- https://socratic.org/questions/how-far-is-the-earth-from-the-edge-of-the-milky-way-galaxy

Using the text and the diagram, students should now write down three facts that can be used to describe the location of the Earth (and our solar system) within the Milky Way Galaxy. Students should be given time to complete this independently and then share out as a whole class.

- Possible answers:
    - *The Milky Way is a spiral shaped galaxy that looks like a pinwheel.*
    - *The sun (solar system) is located between two of the major spiral arms.*
    - *The sun (solar system) appears to be toward the outer part of the galaxy.*
    - *The sun (solar system) is located between the Sagittarius Arm and the Perseus Arm.*
    - *The sun (solar system) is close to or in the Orion Spur (Referred to as the Local Spur Arm on the second diagram).*

Tell students that it's now time to put all this information together and help NASA to design a new golden record.

Tell students: Now that we have updated information on the location of the planet Earth, let's design a new golden record for NASA to include on future spacecraft. Use the template on the student activity sheet to design your idea of what should be included. Include the following in your design:

- A scene or picture that represents something unique to the planet Earth
- A verse from a song that represents important music

- A special greeting in the language of your choice
- The new and improved address of our planet – this may be represented in words, pictures, or a combination of both

Students should use the template on the activity sheet to complete this or teachers may want to provide other teacher-made templates for students to use.

Look for students to indicate that the Earth is part of a solar system which is located on one of the spiral arms of the Milky Way galaxy. It is close to the outer edge and is currently located near or in the Orion Spur.

Citations and Resources

http://www.abc.net.au/science/articles/2014/09/04/4079462.htm
https://www.vox.com/2014/9/4/6105631/map-galaxy-supercluster-laniakea-milky-way
http://earthsky.org/space/does-our-sun-reside-in-a-spiral-arm-of-the-milky-way-galaxy
https://spaceplace.nasa.gov/voyager-to-planets/en/
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amnh.org/education/universe
https://kisd.de/~krystian/starmap/
http://stars.chromeexperiments.com/
https://en.wikipedia.org/wiki/List_of_nearest_stars_and_brown_dwarfs
https://kids.nationalgeographic.com/explore/space/milky-way/#milky-way-2.jpg
http://www.ouruniverseforkids.com/our-galaxy-the-milky-way/
https://www.nasa.gov/jpl/charting-the-milky-way-from-the-inside-out
http://www.ouruniverseforkids.com/super-clusters/
https://www.space.com/25303-how-many-galaxies-are-in-the-universe.html
https://www.universetoday.com/30305/how-many-galaxies-in-the-universe/
https://www.youtube.com/watch?v=VzL7xGzfNlU
https://stardate.org/astro-guide/local-group-0
https://www.ck12.org/c/earth-science/universe/lecture/The-Known-Universe/?referrer=concept_details
http://www.skyandtelescope.com/astronomy-resources/far-closest-star/
https://imagine.gsfc.nasa.gov/features/cosmic/solar_neighborhood.html
https://drive.google.com/file/d/0B2uEjpYLat9LZHBRTDcxanJNQmM/view

Voyager 1 and 2: The Interstellar Mission

In 1977, NASA launched two unmanned spacecrafts named Voyager I and Voyager II. Their mission was to explore Jupiter and Saturn—and beyond to the outer planets of our solar system. This was a big task. No human-made object had ever attempted a journey like that before.

The two spacecraft took tens of thousands of pictures of Jupiter and Saturn and their moons. The pictures from Voyager 1 and 2 allowed us to see lots of things for the first time. For example, they captured detailed photos of Jupiter's clouds and storms, and the structure of Saturn’s rings.

Voyager 1 and 2 also discovered active volcanoes on Jupiter’s moon Io, and much more. Voyager 2 also took pictures of Uranus and Neptune. Together, the Voyager missions discovered 22 moons.

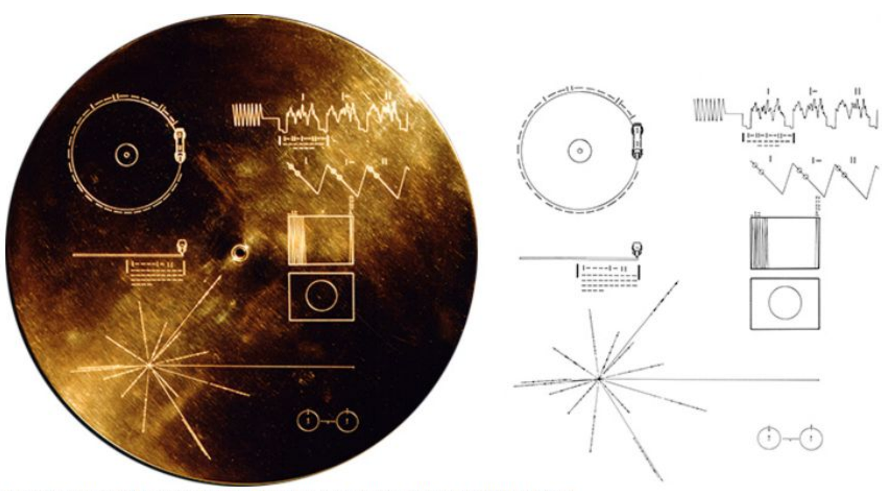
Since then, these spacecraft have continued to travel farther away from us. Voyager 1 is so far away that it is now in interstellar space—the region between the stars. Voyager 2 is in the very outer part of our solar system. No other spacecraft has ever flown this far away.

Both spacecraft are still sending information back to Earth. This data will help us learn about conditions in the distant solar system and interstellar space.

The Voyagers have enough fuel and power to operate until 2025 and beyond. Sometime after this they will not be able to communicate with Earth anymore. Unless something stops them, they will continue to travel on and on, passing other stars after many thousands of years.

Each Voyager spacecraft also carries a message. Both spacecraft carry a golden record attached to the outside of the craft. The records contain scenes and sounds from Earth. The records also contain music and greetings in different languages. So, if intelligent life ever find these spacecraft, they may learn something about Earth and us as well!

Retrieved from: https://spaceplace.nasa.gov/voyager-to-planets/en/



The Golden Record cover shown with its extraterrestrial instructions. Credit: NASA/JPL

Voyager 1 and 2: The Interstellar Mission

Included in the information on the golden record is a “map” showing how to find the planet Earth in the universe. It’s in the lower left of the record and looks like a “starburst.” It shows the location of 14 special stars called pulsars that would serve as a guide to the location of our planet. However, we have a problem! It turns out that the “address” is now wrong!

Since 1977, over a BILLION pulsars have been discovered! Although it was a very clever idea presented just 10 years after the discovery of pulsars, we now know that Voyager’s cosmic map to find Earth will be hopelessly wrong by the time an alien civilization finds it.

Today, we have much more information about the location of our Earth in space. If NASA wanted to design a new golden record with the updated location of the planet Earth, what information would we need to include? We don’t want to miss an opportunity to make contact with extraterrestrials from outer space!

1. Let’s start with what we know.
   Mark the Earth’s location in the diagram below.

   Describe where Earth is located in our solar system. Be as detailed as possible so that other intelligent life can find us.

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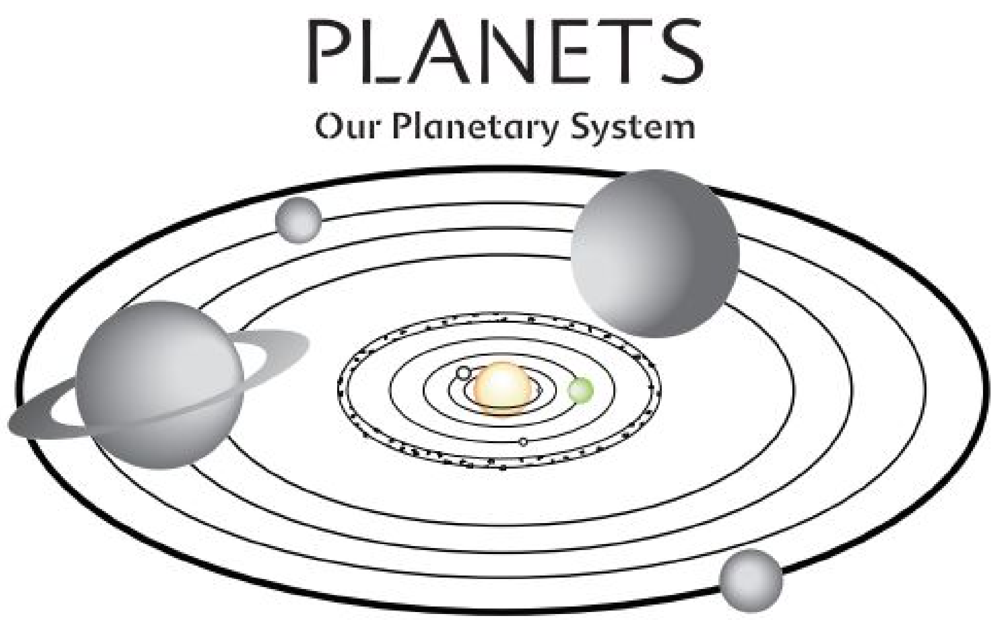

Voyager 1 and 2: The Interstellar Mission

2. Our sun is the largest object in our solar system. However, when we look up into the night sky, there are so many stars! How can we describe where our star, the sun, is located?

   We need to create a map of "our stellar neighborhood." This would show where our sun and the stars that are closest to us are located.

   The table below shows the names of the stars that are closest to our sun and are part of our stellar neighborhood. The table also shows how far away each star is from our sun.

Proxima Centauri	4.22 light years (ly)
Barnard's Star	5.97 ly
Wolf 359	7.7 ly
Sirius A & B	8.6 ly
Epsilon Eridani	10.5 ly
Ross 128	10.8 ly
Procyon	11.4 ly
Tau Ceti	11.9 ly
Altair	16.3 ly
Eta Cassiopeiae	19 ly

Retrieved from:
https://imagine.gsfc.nasa.gov/features/cosmic/solar_neighborhood_info.html

What other information do we need to be able to create a map of our stellar neighborhood that would help extraterrestrials find us?

____

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Click here (https://kisd.de/~krystian/starmap/) to create a map showing the location of our sun and the stars closest to us. Place the sun in the middle and then graph and label the stars that are closest to our sun. Note that the website only shows stars that are within 14 light years of our sun.

3. Stars, planets, and clouds of gas and dust are all collected into galaxies where they are held together by a force called gravity. Galaxies are huge and can have billions of stars in them. Read the following text to learn about the galaxy in which our solar system is located – the Milky Way! Underline information that will be important in explaining to extraterrestrials where our solar system is located in the Milky Way Galaxy.

The Milky Way Galaxy

The Milky Way is a huge collection of stars, dust, and gas. It's called a spiral galaxy because if you could view it from the top, it would look like a spinning pinwheel. The Sun is located between two of the spiral arms, about 25,000 light-years away from the center of the galaxy. Even if you could travel at the speed of light (186,000 miles per second), it would take you about 25,000 years to reach the middle of the Milky Way.

Photo Credit: NASA/JPL

The Milky Way gets its name from a Greek myth about the goddess Hera who sprayed milk across the sky. In other parts of the world, our galaxy goes by other names. In China, it's called the "Silver River," and in the Kalahari Desert in Southern Africa, it's called the "Backbone of Night."

If you could see our galaxy from the side, it would look like a huge, thin disk with a slight bump in the center. This flat shape is caused by the galaxy spinning around. Everything in our spinning galaxy would fly off into space if it weren't for the force of gravity.

Voyager 1 and 2: The Interstellar Mission

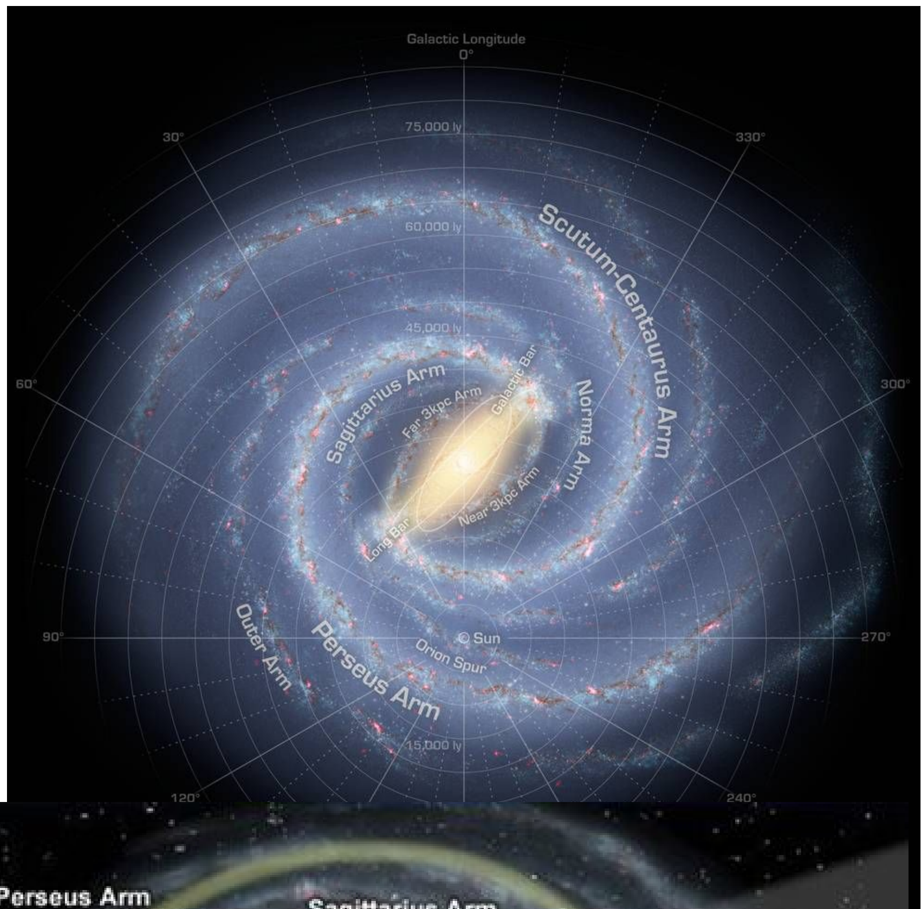
Photo Credit: NASA/JPL

Milky Way as seen from the side

Without a telescope, we can see about 6,000 stars from Earth. That may seem like a lot of stars, but it’s actually only a small part of the whole. If you think of the entire galaxy as a giant pizza, all the stars you can see from Earth fall within about one pepperoni on that pizza. In fact, for every star you can see, there are more than 20 million you cannot see. Most of the stars are too faint, too far away, or blocked by clouds of cosmic dust.

Retrieved from:https://www.amnh.org/ology/features/milkyway/

4. Examine the pictures of the MIlky Way Galaxy shown below.



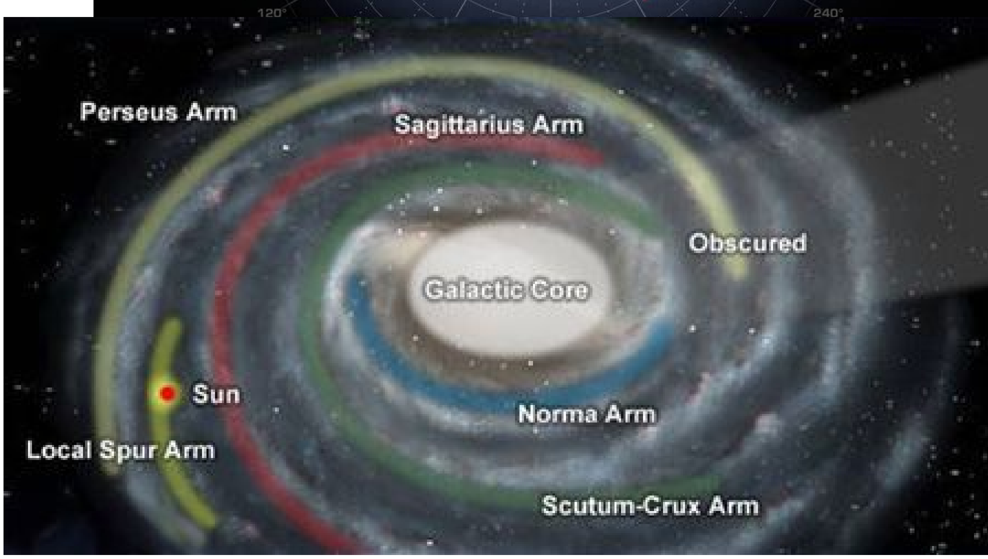


Image retrieved from www.daviddarling.info

Using the text and the pictures above, identify three specific facts to help describe the location of our solar system within the Milky Way Galaxy.

a. ____

____

b. ____

____

c. ____

____

5. Now that we have updated information on the location of the planet Earth, let's design a new golden record for NASA to include on future spacecraft. Use the template below for your idea of what should be included. Include the following in your design:
    - A scene or picture that represents something unique to the planet Earth
    - A verse from a song that represents important music
    - A special greeting in the language of your choice
    - The new and improved address of our planet – this may be represented in words, pictures, or a combination of both

Tab page front

Label: Analyzing and Interpreting Data

Analyzing and Interpreting Data

Tennessee Academic Standards for Science

Teacher Guide for Grade 5

Standard
5.PS1.2 Analyze and interpret data to show that the amount of matter is conserved even when it changes form, including transitions where matter seems to vanish.

Tennessee Academic Standards for Science: Page 42

Three-dimensional Learning Performance for Lesson
Students will analyze and interpret data* in order to show that matter is conserved even when it changes form**, highlighting that matter is conserved even in transitions where it seems to vanish.***

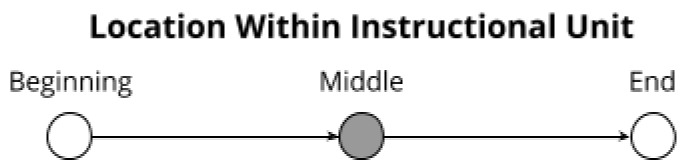
Science and Engineering Practice for Lesson
*Analyzing and Interpreting Data**
The goal of this three-dimensional learning performance is for students to collect and analyze data from simple investigations to establish the concept that mass is conserved in both physical and chemical changes.

Disciplinary Core Idea for Lesson
*Physical Science: Matter and Its Interactions***
When two or more different substances are mixed, a new substance with different properties may be formed; such occurrences depend on the substances and the temperature. No matter what reaction or change in properties occurs, the total weight of the substances does not change. Boundary: Mass and weight are not distinguished at this grade level.

A Framework for K–12 Science Education: Pages 110-111

Crosscutting Concept for Lesson
*Energy and matter****
Students will analyze and interpret data tracked from multiple investigations in order to explain the Law of Conservation of Mass through observation of patterns in matter transformation.

Prior Knowledge



- Concepts that should be covered before this lesson:
    - 5.PS1.1 Analyze and interpret data from observations and measurements of the physical properties of matter to explain phase changes between a solid, liquid, or gas.
    - 5.PS1.4 Evaluate the results of an experiment to determine whether the mixing of two or more substances result in a change of properties.
    - Physical and chemical changes are not formally introduced at this time, but it is important to include both types of changes as investigations during the exploration of conservation of mass.
- This lesson covers portions of standard 5.PS1.2:
    - Analyze and interpret data to show that the amount of matter is conserved even when it changes form, including transitions where matter seems to vanish.

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

- Pan balances or beam balances
- Ice cubes
- Snack-sized sealable bags
- Large cookie that can be broken into parts
- Play-Doh
- Water
- Paper
- Sugar packets
- Baking soda
- Vinegar
- Empty 500mL plastic bottles (one for each group)
- Balloons
- Plastic spoons
- Small plastic/paper cups
- Goggles

Lesson Sequence and Instructional Notes

The goal for this lesson is for students to observe several simple investigations and collect data about the mass changes in each. The lesson begins with a teacher demonstration and then asks students to continue to perform a series of experiments, each exploring a different change in matter. Students measure the mass of the matter both before and after the change. Finally, the teacher will facilitate the analysis and interpretation of the data, eventually leading students to the discovery of the Law of Conservation of Mass.

Critical teaching points[1]:

- Matter is not created or destroyed in ordinary changes.
- In any change involving matter, all of the matter must be accounted for. Matter does not turn into or appear from energy in ordinary chemical reactions.
- In a chemical reaction, particles are rearranged to create substances different from the original.
- There is no change in mass when substances move in and out of different states, i.e. from solid to liquid.

Teacher Demonstration

Begin the lesson by showing students a large cookie that can be easily broken into pieces. It is best to place the cookie into a sealable plastic bag so that no crumbs will be lost. Obtain the mass of the cookie using a simple pan or electronic balance. Write the mass (in grams) on the board so that all students can see the value.

Explain that you are going to break the cookie into several pieces and then obtain the mass of the pieces. Ask them to write their prediction of how the mass will change in the Predict-Observe-Explain Table on the student activity sheet. Invite students to share their predictions or poll the class if appropriate.

As you crush the cookie or break it into pieces, have students complete the “observation” portion. Note that students might describe the number of pieces, crumbs, etc., but it is also important for them to note that the bag stays sealed.

Finally, obtain the mass of the broken pieces again. The mass should remain exactly the same. Ask students to note the mass of the pieces in the “explain” section and then explain why the mass of the pieces is exactly the same as the mass of the whole cookie.

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[1] Retrieved from:http://www.education.vic.gov.au/school/teachers/;;teachingresources/discipline/science/continuum/Pages/mattermass.aspx

Reflections about possible students responses

- The most common misconception is that since there are smaller pieces, the mass must also be smaller as well. Stress to students that the whole cookie is still there, even though it is now in smaller pieces.
- Some students might wonder what would happen if some crumbs escape the sealed bag. However, in both situations, the whole cookie is still there.

Develop a class question

As a class, guide students toward the development of a question that can be answered through investigation.

- Is mass always conserved in every change? How can we find out?
- What kind of changes could we examine?
- What tools or pieces of equipment would we need to do our investigation?

The goal is for the class question to be something that the students attempt to answer through the completion of the investigations.

Sample Class Question: Is matter conserved in all kinds of changes, including ones where the matter seems to vanish?

Once the students agree on a focus question for their investigations, hand out the Student Activity Sheet and have students record the question in part one.

Student Investigations

Each investigation addresses a major type of change in matter. Note that Investigations D and E deal specifically with matter that seems to "vanish."

Investigation A: Phase Change of Matter (Physical Change)
Investigation B: Change in Shape of Matter (Physical Change)
Investigation C: Breaking matter into parts (Physical Change)
Investigation D: Dissolving (Physical Change)
Investigation E: Chemical Reaction (Chemical Change)

Teachers may choose to complete the student investigations in a manner appropriate to their class. The advantage of a guided approach in this situation is that it allows for discussion of each investigation before students move to the next experiment.

Investigation A

(Note that the investigation involving ice is intentionally done first to allow time for the phase change to occur. Students can set this investigation up and proceed with the others while the ice is melting. Teachers may choose to do this as a class demonstration at the beginning of the lesson, and then return to this for data collection after the student-led investigations have been completed.)

Each group of students should be given one snack-size plastic bag with one, two, or three small ice cubes. Small cubes or even ice chips may work best. An optional variation is to intentionally provide student groups with different amounts of ice in the beginning. This allows students to observe that the total mass of the ice is the same as the total mass of the liquid water after melting. The conservation of mass always holds true and does not depend on the original starting mass. Make sure the bags are sealed and do not have any openings.

Ask students to draw a picture showing the properties of the ice in the sealed bag. Students should then obtain the mass of the sealed bag and ice, and record that on the student activity sheet. Note that mass should be measured in grams. At this point, students should place the ice in a designated location and move on to the next investigations.

When the ice has melted, students should again draw a picture to show the change in matter that has occurred, and obtain the mass of the water. Note that it is not necessary for the ice to completely melt. The idea is for students to see that a change in state does NOT change the mass of the substance.

Possible Teacher Questions

- How can we describe the change in matter we observed?
- What caused the change?
- What does the data show about mass and change of state?
- What would happen to the mass if the water froze and became a solid again?
- What would happen to the mass if the water was boiled and turned into steam? (Assume that the steam could be captured and weighed on the balance.)
- Is the mass conservation true for every phase change?
- Is the mass conservation true for all substances or only water?

Teacher Background Knowledge

Ice floats due to a difference in the density of solid ice versus the density of liquid water. Density is a ratio of mass AND volume. However, density is not within the scope of this standard. Therefore, redirect students back to the data from the experiment, to show that there is no difference in the mass of the ice cubes and the liquid water that is produced.

Investigation B

Provide each group of students with a small amount of Play-Doh. Ask them to draw a picture on their activity sheet showing the shape of the Play-Doh. Have students take the mass of the Play-Doh and record the mass in the student activity sheet. Allow students to have a few minutes to reshape the Play-Doh. Have them draw a picture of the new shape and record the mass again. The mass should remain the same.

Possible Teacher Questions:

- How can we describe the change in matter that we observed?
- What caused the change?
- What does the data show about mass and change of shape of a substance?
- What would happen to the mass if we reshaped the Play-Doh yet again?
- What is the only way that the mass WOULD change? (Add or subtract some Play-Doh.)
- What other examples of changing shape can you think of? Would the mass change in any of these examples?

Reflections on Possible Student Responses

- Most students will be comfortable with the idea that changing the shape of a material does not alter the mass. Crushing an aluminum can or wadding up a piece of paper are both additional easy demonstrations.

Investigation C

Provide each group of students with a small sheet of paper. Construction paper may work best depending on the sensitivity of the balance. Have students draw a picture of the whole piece of paper and obtain the mass. Ask students to tear the paper into several pieces, being careful not to lose any of the pieces! Have them draw a representation of the torn pieces of paper and obtain the total mass of the pieces of paper. The mass should remain the same.

Possible Teacher Questions

- How can we describe the change in matter that we observed?
- What caused the change?
- What does the data show about mass and breaking the substance into parts?
- What other examples of this change can you think of?

Reflections on possible student responses

- Students should observe that breaking a whole into parts does not affect the mass of the substance as long as no part is lost or missing. For example, the mass of a whole candy bar should equal the total mass of the candy bar if broken into pieces. Because students can see all of the parts, most students easily accept that the total mass of the parts will be equal to the mass of the whole.

Investigation D

Provide each group of students with a small cup of water, a plastic spoon, and a packet of sugar. Ask students to draw a picture of the cup of water, the plastic spoon, and the packet of sugar. Obtain the total mass of the items and record it on the student activity sheet.

Have students carefully tear open the packet of sugar while holding it over the cup of water. They need to make sure that the sugar goes directly into the water. They also need to make sure that they only tear the sugar packet and don't accidentally lose part of the sugar packet paper. Have them gently stir the water until the sugar dissolves. It is not necessary for all the sugar to dissolve, but students do need to see that the sugar has "disappeared."

Students should draw a picture showing the water after the sugar has been dissolved. They should include the open sugar packet and spoon. (It is important that all the original items are present in the "after" picture.) Students should obtain and record the mass of the dissolved sugar, spoon, and empty sugar packet. The mass should remain the same.

Possible Teacher Questions

- How can we describe the change in matter that we observed?
- What caused the change?
- What does the data show about mass and dissolving a solid into a liquid?
- Where did the sugar go? How could we get the solid sugar back?
- What other examples of dissolving can you think of?
- How could you show in your picture that the sugar particles are still present in the water?

Reflections on possible student responses

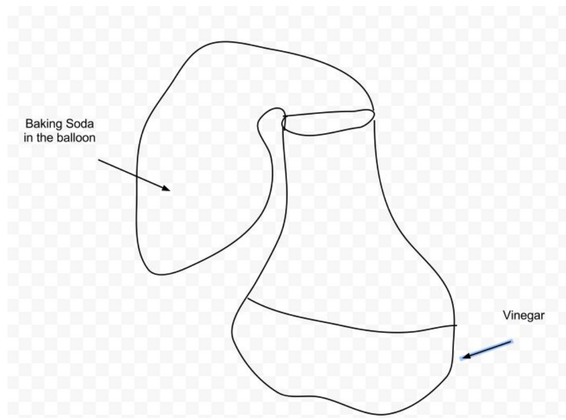
- Dissolving a solid into a liquid is a physical change that can be difficult to understand for many students. The sugar seems to disappear and thus, many students might think the mass of the dissolved sugar in water would decrease.
- The sugar and water do not combine to create a new substance but only combine to create a mixture of sugar and water. If the water were to evaporate or be boiled off, the sugar crystals could be recovered. Because this process results in the sugar no longer being visible, it would be advisable to show a simulation or animation of the process to assist student understanding that the sugar (and thus the mass of the sugar) is still present.

- Animation of Sugar Dissolving

Investigation E

This investigation can be done as a demonstration.

- Place about 50 mL of vinegar into an empty plastic 500 mL bottle.
- Measure out about 2 teaspoons (8-10 grams) of baking soda.
- Place the baking soda into the balloon.
- Carefully attach the balloon to the mouth of the bottle, being careful not to allow any of the baking soda to come into contact with the vinegar. The balloon should hang over to the side of the bottle.



Have students add a diagram to show the set-up.

Obtain the mass of the balloon/bottle system and have students record the mass.

- Carefully shake the baking soda into the vinegar in the bottle. A chemical reaction will take place producing easily visible bubbles. The gas causes the balloon to inflate.
- Encourage the students to share their observations. Ask students why the bubbles are forming. (Carbon dioxide gas is produced by the reaction. This gas inflates the balloon.)

Have students sketch a diagram of the balloon/bottle AFTER the reaction takes place. Ask students to predict whether the mass has changed. Obtain the mass of the system and have students record this on their activity.

Note: Depending on the sensitivity of the balance, students may find that the mass of the balloon/gas AFTER the reaction actually decreases by around 1.0 gram. This occurs mainly due to a slight amount of gas seeping out of the balloon itself. Teachers may choose to use this as an opportunity to discuss what the data actually shows. Remind students that birthday balloons, for example, don't stay inflated forever. So, the gas produced is still there, although a slight amount has escaped into the air around the balloon.

Finally, ask students what will happen to the mass if the gas from the balloon is released. Gently "burp" the balloon and release the gas. Allow students to create one final sketch. *Encourage them to include gas bubbles going into the air as part of their sketch.* Obtain the mass and have students record this in the data table.

Possible Teacher Questions

- How can we describe the change in matter that we observed?
- Where did the gas bubbles come from?
- Was any new matter introduced into the bottle?
- How was this investigation different from the ones already completed?
- Why did the mass decrease after the balloon was released?
- Was any matter destroyed?

Reflections on possible student responses

- Students at this grade level have not been formally introduced to chemical reactions on the atomic or molecular level. However, most students will probably respond that something new was made (bubbles), which had to come from what was already in the bottle. The idea here is to reinforce the idea that substances can combine to create new substances with different properties. However, even in a chemical reaction, the total mass of the new substances made will still equal the total mass of the beginning substances.
- Some students may note that the beginning substances were a liquid (vinegar) and a solid (baking soda), and yet a gas was made from combining the two. The gas is only one of the new substances made. The liquid in the bottle has also been changed as well.
- Ultimately, the focus should be on the conservation of mass throughout the process. Only when the gas is released into the air does the mass of the system decrease significantly, and yet the matter is still there. No matter has been destroyed. Thus, it is important to have students include the “bubbles” being released into the air in their final drawing.
- Additional video clips demonstrating conservation of mass in a chemical reaction are readily available: https://www.youtube.com/watch?v=Wwmsy4huZQ0

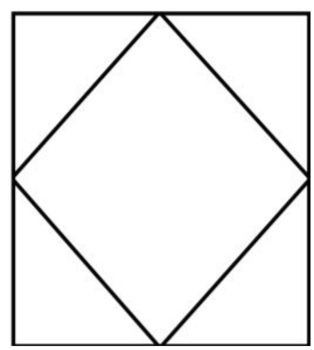
Analysis and Interpretation of Data

Differences	Similarities
Investigation A: Change of state Investigation B: Change of shape Investigation C: Change in sizes Investigation D: Dissolving/Mixture Investigations A-D: Nothing new is made Investigation E: Something new was made Different substances were used in each investigation.	In all cases, the total mass “before” was equal to the total mass “after” the change was made.

The two questions that follow are crucial in establishing the idea of conservation of mass.

- Describe the pattern that you see in the data. The total mass always stays the same before and after each change, even when you can’t see the matter anymore.
- Based on your evidence, what conclusion can you make about mass? Matter (or mass) is not created or destroyed. It can change form and sometimes combine to make something new, but all the matter (mass) is still there.

Formative Assessment



It is important to help students reach a consensus that establishes the Law of Conservation of Mass. Students might state this differently, however, all groups should be able to describe the fact that matter does not just “vanish”. In a physical change, matter changes form but remains the same substance. In a chemical change, matter changes form and a new substance is made. In both cases, the total mass of the reactants will always equal the total mass of the products. One method for helping students achieve this is presented below:

Setup: Each small group or table needs a copy of a graphic organizer that looks like the image to the right. Each student will write on one of the triangular “corners” of the organizer.

1. The teacher poses a question that students can answer with data.
2. All students get three minutes to think and write their thoughts in their respective corner.
3. The students take turns explaining their ideas to each other (all students must share).

4. The students discuss what their consensus view might be and write their consensus view in the middle.
5. Share out so that consensus can be reached by the class as a whole.

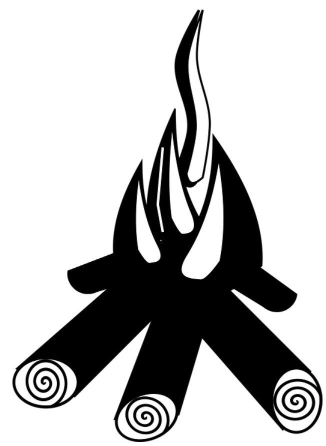
Class consensus should reflect the following

- Establish the Law of Conservation of Mass.
- Reinforce that matter is never created or destroyed.
- Total mass of the matter is always the same BEFORE and AFTER a change.
- Sometimes, it may seem as if matter "disappears," but it is always still there.

Notes:

1. This makes a good formative assessment artifact.
2. Coming to a consensus is really hard work and can be emotional. Remind students that coming to a consensus is about arguing about ideas, not arguing with people. You might have to scaffold participation even further and hold class debriefs about how the argument process itself went for different groups.

If you build a campfire, you start with a big pile of logs. As the fire burns, the pile of logs slowly shrinks. By the end of the evening, all that's left is a small pile of ashes. The mass of the ashes is less than the mass of the original logs.



Circle all of the claims that are true:

A. The mass of the ashes will be less than the mass of the logs because some of the matter in the logs was destroyed as it burned.

B. The mass of the ashes is less than the mass of the logs because some of the wood turned into gas which went into the air.

C. The mass of the ashes left will be less than the mass of the logs because some of the wood melted.

D. The mass of the ashes left will be less than the mass of the logs because the process of burning changes some of the log into a different substance that you can no longer see.

E. The mass of the ashes left will be less than the mass of the logs because the logs have been broken apart into thousands of smaller pieces.

Answer(s) and Justification

A is incorrect. Matter is neither created nor destroyed.

B is correct. The process of combustion produces carbon dioxide gas which is then released into the air in this example.

C is incorrect. The wood does not “melt.” The process of burning, in its simplest form, produces carbon dioxide gas, water vapor, and ashes.

D is correct.

E is incorrect. The ash is one of the products from the combustion reaction. The log was not broken into thousands of smaller pieces.

Student answers should include that breaking matter into pieces, such as with the cookie, does not change the total mass of the matter. No matter what kind of change occurs, the mass of the matter stays the same before and after.

Citations and Resources

Cookie Crumbles Formative Probe Idea and Ice Cubes Melting Formative Probe:
Keeley, P., F. Eberle, and L. Farrin. 2005. Uncovering student ideas in science: 25 formative assessment probes

Critical teaching points:
http://www.education.vic.gov.au/school/teachers/teachingresources/discipline/science/continuum/Pages/mattermass.aspx

Description of prior knowledge (last paragraph) from:
http://www.education.vic.gov.au/school/teachers/teachingresources/discipline/science/continuum/Pages/research.aspx#r
https://www.ck12.org/book/CK-12-Physical-Science-Concepts-For-Middle-School/section/2.10/
https://madelineisn.weebly.com/conservation-of-mass-lab.html

Discussion Diamond

Chocolate Chip Cookie Clipart

Sugar Dissolving Video Clip

Chemical Reaction Demonstration of Law of Conservation of Mass

Campfire Clipart

Imagine you have a whole cookie. You break the cookie into tiny pieces and crumbs. How do you think the mass of the whole cookie compares to the total mass of all the cookie crumbs?

Predict	Observe	Explain

Name: ______________________________

Part 1: Question

The following investigations will provide data that we can analyze and interpret in order to answer the following question:

____

____

Part 2: Data collection

Record your data and observations for each of the investigations below.

A.

Solid Ice Cubes	Liquid Water
Picture	Picture
Mass:	Mass:

How can we describe the change in matter we observed? ___________________________

____

What does the data show about mass in this type of change? _________________________

____

What would happen to the mass if the water froze and became a solid again? _________

____

What would happen to the mass if the water was boiled and turned into steam? (Assume that the steam could be captured and weighed on the balance.) ________________________

____

Is the mass conservation true for all substances or only water? How could we find out?

____

____

B.

Initial Shape of Playdough	New Shape of Playdough
Picture	Picture
Mass:	Mass

How can we describe the change in matter that we observed? ____________________________

____

What does the data show about mass and this type of change? ___________________________

____

What is the only way that the mass WOULD change? ____________________________________

What other examples of this type of change can you think of? Would the mass change in any of these examples?

____

C.

Whole Piece of Paper	Paper in Pieces
Picture	Picture
Mass:	Mass:

How can we describe the change in matter that we observed? ______________________________

____

What does the data show about mass and this type of change?

____

What other examples of this change can you think of? ____

____

D.

Water and Sugar BEFORE Dissolving	Water and Sugar AFTER DIssolving
Picture:	Picture
Mass:	Mass:

How can we describe the change in matter that we observed? ______________________________

____
_

What does the data show about mass and this type of change? ____________________________

____
_

Where did the sugar go? How could we get the solid sugar back? __________________________

____

What other examples of this type of change can you think of?

____

____

In the example above, modify the picture to show that the sugar particles are still present in the water AFTER the change.

E.

Bottle, baking soda, balloon, and vinegar BEFORE combining	Bottle, baking soda, balloon, and vinegar AFTER combining	Bottle, baking soda, balloon, and vinegar AFTER releasing gas
Picture	Picture	Picture
Mass:	Mass:	Mass:

1. How can we describe the change in matter that we observed? __________________________

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2. Where did the gas bubbles come from? ______________________________________

3. How was this investigation different from the ones already completed? ____________

____

5. Why did the mass decrease after the balloon was released? ____________________

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Part 3: Analyze and Interpret Data

Analyze each of the investigations above to identify ways that they are the same and ways that they are different.

Differences	Similarities

1. Describe the pattern that you see in the data.

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2. Based on this evidence, what conclusion can you make about mass?

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Part 4: If you build a campfire, you start with a big pile of logs. As the fire burns, the pile of logs slowly shrinks. By the end of the evening, all that's left is a small pile of ashes. The mass of the ashes is less than the mass of the original logs. Circle all of the claims that are true:

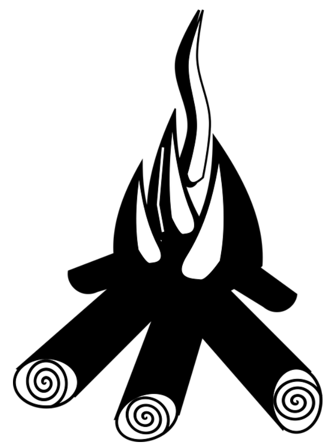
A. The mass of the ashes will be less than the mass of the logs because some of the matter in the logs was destroyed as it burned.

B. The mass of the ashes is less than the mass of the logs because some of the wood turned into gas which went into the air.

C. The mass of the ashes left will be less than the mass of the logs because some of the wood melted.

D. The mass of the ashes left will be less than the mass of the logs because the process of burning changes some of the log into a different substance that you can no longer see.

E. The mass of the ashes left will be less than the mass of the logs because the logs have been broken apart into thousands of smaller pieces.



Part 5: How would you explain the conservation of mass to a friend? Use the cookie example from the beginning of the activity as evidence in your answer. You should also include at least one other example from this lesson as evidence, but you may include other examples as well.

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